Science For Secondary Schools

SCIENCE

PART II

Class X

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Class X

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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Foreword

This book is based on a new course for Classes IX and X, aimed at creating an understanding of some of the fundamental concepts, such as matter, energy, motion, structure of the atom, chemical bonding, organisation of life, life processes, and so forth, while at the same time making the pupils aware of some of the basic problems of environment, population, ecosystem, natural resources, nutrition and health, along with some plausible solutions. It is hoped that such a single course in science would provide a basic knowledge of science for all and a reasonable scope for specialisation for those opting for the science stream in their higher studies. It is also hoped that the overall content matter of the present course would arouse active interest in the universe around us and in some of the relevant phenomena in nature which are part of our everyday life.

The sequencing of topics in the present course has been so done as to facilitate learning as well as to bring out the fact that the different areas of science are interlinked in one way or the other. For instance, some of the sophisticated areas of chemistry (say, rates of reactions, electrolytic dissociation) have been introduced only after the student understands the underlying physical principles. Similarly, the areas of life sciences have been so arranged as to bring about a better understanding of the living systems by utilizing the knowledge of the chemistry of oxygen, phosphorus, nitrogen and carbon gained earlier. In the present textbook, the subject-matter has been presented so as to reduce the overall burden on the pupils, and the approach has been made more meaningful in the sense that teaching-learning in science is not dependent on the availability of a sophisticated laboratory and equipment.

The Council is grateful to the members of the various editorial boards, to the practising teachers and experts and also to Dr. K. N. Mehrotra and Dr. S. Lokanathan for editing the portions related to chemistry and physics and to Shri K. B. Gupta for going through the portion on life sciences.

The Council is also grateful to the staff members of the Department of Education in Science and Mathematics who have been instrumental in developing the course and have completed the work in a very short time.

Suggestions for improvement of the book would be most welcome.

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New Delhi
17 April 1979

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Chapter 19

Wave Motion

19.1 Waves

If we drop a stone in a pond or a pool of water, we notice that the disturbance of the water moves outward. Ripples form and move like expanding rings. This movement of water is an example of wave motion.

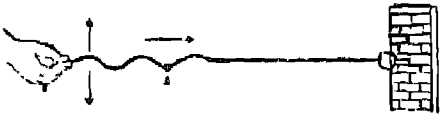


Fig. 19.1 Transverse wave motion in a rope

An easy way to produce wave motion is to tie one end of a long rope to a window bar or a hook on the wall. If the free end is moved up and down, the disturbance will be seen to travel along the rope (Fig. 19.1). Another example, somewhat more difficult to try, is the following.

Imagine a system of trolleys linked together by springs. The spring attached to the last trolley A is pulled (Fig 19 2) and then released immediately. It will be observed that the trolley B will move to the right, followed by the trolleys C, D, and so on. Thus, a disturbance started at one end travels to the other end.

Let us see, from these examples, what common features of wave motion are. A disturbance started at one place progressively moves along. This progressive movement takes place through a medium, for example, water, rope and springs in the above three cases. Notice that although the *disturbance* travels from one region of the medium to another, no part of the medium travels very

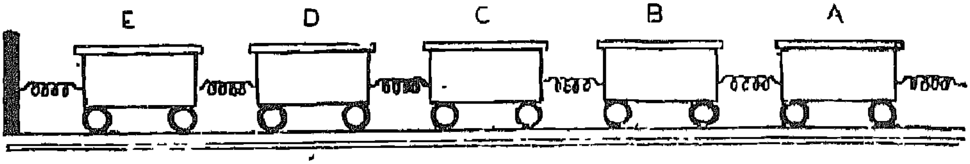


Fig. 19.2 Propagation of a longitudinal vibration

far from its mean position. For example, in the trolley experiment, each trolley moves back and forth but does not progress with the wave. Similarly, in the case of the rope, the particles of the rope move up and down but again do not progress with the wave.

If we look carefully at these examples, we will notice that there are two types of wave motion. In the case of the rope, the particles vibrate at right angles to the direction in which the wave travels. Such waves are called *transverse waves*. In the case of trolleys, they vibrate back and forth along the direction in which the wave travels These waves of compression and rarefaction are called *longitudinal waves*.

19.2 Characteristics of a wave

Let us consider, again, our example of a long rope tied to a window bar. If we keep moving one end up and down, the disturbance propagates along the rope and at a particular instant the rope looks as in Fig. 19.3. The extreme

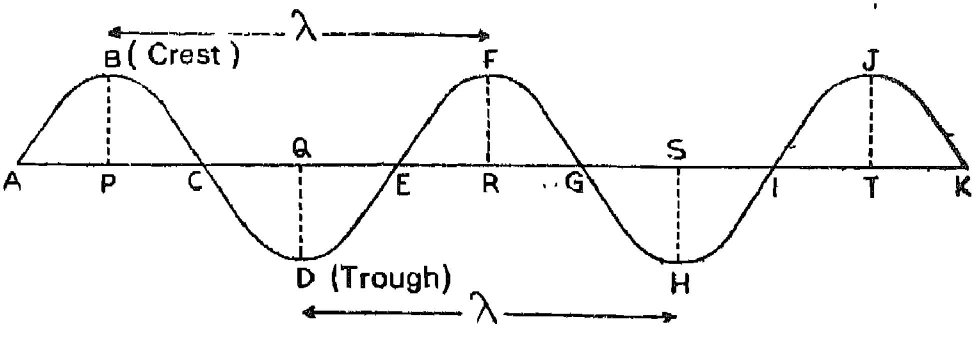


Fig. 19.3 Characteristics of a transverse wave

positions of vibrations of the rope are marked *crests* and *troughs*. The distance between the two consecutive crests or two consecutive troughs is called the *wavelength* and is usually denoted by the Greek symbol λ. In Fig. 19.3 the distance BF or DH gives the wavelength. The maximum displacement of a particle from its position of equilibrium is called *amplitude* of the wave. In the figure, BP, DQ, FR and HS give the amplitudes.

The time during which a particle of a medium completes one full vibration (starting at a crest, going to a trough and returning to the crest) is called the *time period*. It is usually denoted by T. Thus, one full vibration or *cycle* takes T second. In one second, therefore, 1/T cycles are completed. This number of cycle produced per second is called the *frequency* of the waves and is denoted by the Greek letter ν. Thus, the frequency $\nu=1/T$. The frequency, therefore, gives the number of times per second the wave pattern is produced. If 10 waves are produced per second, we say that the frequency is 10 cycle per second or simply 10 *hertz*. The hertz (Hz) is a *unit of frequency*.

19.3 Relation between velocity, wavelength and frequency

One important question must have occurred to us. How fast does a disturbance travel, i.e., how fast do waves move ? Waves, in other words, propagate with a velocity v. This is just the distance through which a disturbance moves along a medium in one second. As we speak, sound waves are produced and travel with a velocity of about 330 m/s. This is the velocity of sound in air. Sound travels much faster in solids and liquids.

Frequency, wavelength and velocity are related to one another. Since wavelength is the length of a single wave and frequency is the number of waves produced in one second, their product is the distance through which waves travel in one second. Thus, the velocity v is given by the relation.

$$v=\nu\lambda \qquad \ldots(19-1)$$

19.4 Waves carry energy

A moving body, such as a football, can transfer energy from one place to another. From our study of waves, we can see that the transfer of energy can also take place by wave motion. Both in transverse and longitudinal motion, the energy transferred to the medium by the source of disturbance is propagated along the direction of motion of the waves. When a jerk is given to the rope, or a stone is dropped in a pool of water, the kinetic energy of the hand or the stone is transferred to the moving particles near the point of disturbance. These particles vibrate with a part of the imparted kinetic energy and the remaining energy is transferred to the particles of the next layer. Particles of the layer vibrate with a part of the received energy and the remaining energy is transferred to the next layer. In this way, energy is transferred in a medium during wave motion.

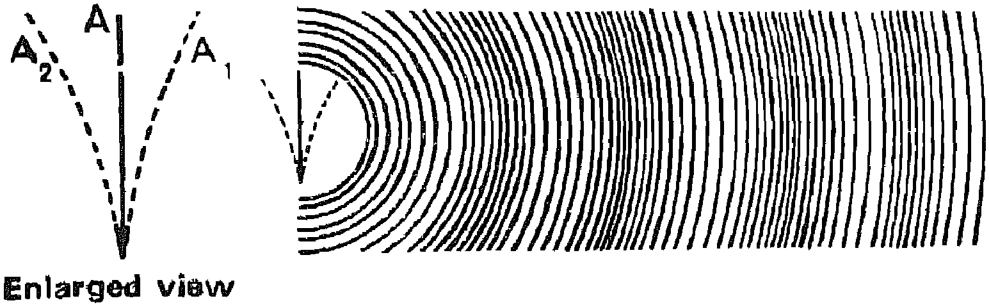


Fig. 19 4 Longitudinal waves in air

19.5 Sound waves and ultrasonics

Sound waves that reach our ear are longitudinal waves They require a medium to transfer energy When a source of sound vibrates, the particles of the medium vibrate about their mean positions. Suppose, sound is produced by a vibrating foil. The air surrounding the foil is composed of atoms of various gases. When the foil moves forward (AA_1 position), it exerts pressure on the layers of air in front of it. The pressure is transmitted to the adjacent layers (Fig. 19.4). Thus, a wave of compression moves forward. When the foil moves backward (AA_2 position), the pressure decreases and air from the higher pressure region rushes in. So, a wave of rarefaction follows the wave of compression. So long as the foil vibrates, there will be alternate variations of pressure in the medium. These disturbances gradually spread in all directions. When these disturbances reach our ear, the eardrum vibrates and we hear the sound.

So, for sound waves we require a source and a medium through which they can travel. These waves utilize the elastic properties of the medium for its propagation. So, they are also called *elastic waves*. Water waves are also elastic waves.

The velocity of sound is different in a different medium In air, it is 330 m/s; in water. it is 1400 m/s; and in iron, 5000 m/s. The velocity of sound is higher in a denser medium. The velocity also increases with the increase in temperature of the medium.

We can hear vibrations between 20 Hz to 20,000 Hz. This limit is called the *audible limit* and varies slightly with individuals and age Waves with frequencies above 20,000 Hz are called *ultrasonic waves* and those below 20 Hz are called *infrasonic waves*.

Man cannot hear ultrasonic waves. Bats have a very high range of audible limit. They can hear and produce waves up to 100,000 Hz. During their flights, they produce ultrasonic waves and hear the echo. Dogs can hear up to 20,000 Hz.

19.6 Light waves do not require a medium

From what we have learnt so far, it would seem that wave motion always requires a medium. Yet, surprisingly, there is a class of waves which do not require a medium for propagation at all. These are called *electromagnetic waves*. Light, which we detect with our eyes, is an example of electromagnetic waves. In fact, we know that light energy is transported from the sun or other stars through vast distances in empty space. The velocity of these electromagnetic waves in vacuum is 3×10^8 m/s.

Light, as we have just said, is the visible portion of the electromagnetic waves. Each colour of a *spectrum* corresponds to a different wavelength or frequency. The frequency of the visible range lies between 4×10^{14} Hz to 7.5×10^{14} Hz. Red light has a higher wavelength and a shorter frequency than violet light. The wavelengths are so small that it is customary to give these wavelengths in a new unit of length called the *angstrom*, denoted by the symbol $\text{Å} = 10^{-10}$ m. The wavelength of red light is 7800 Å and that of violet light is 4000 Å

Electromagnetic waves below 4000 Å wavelengths are called *ultra-violet rays* and waves with wavelengths higher than 7800 Å are called *infra-red rays*. The different types of electromagnetic radiation are shown in table 19.1.

TABLE 19.1

Types of Electromagnetic Radiation

E.M. Wave	Frequency in Hz	Wavelength in metres
1. Radio waves	0.5×10^{6} to 2×10^{8}	6×10^{5} to 1.5
2. Microwaves	10^{8} to 3×10^{11}	0.3 to 10^{-3}
3. Infra-red	3×10^{11} to 4.3×10^{14}	10^{-3} to 7×10^{-7}
4. Visible light	4.3×10^{14} to 7.5×10^{14}	7×10^{-7} to 4×10^{-7}
5. Ultra-violet light	7.5×10^{14} to 10^{16}	4×10^{-7} to 3×10^{-8}
6. X-rays	10^{16} to 3×10^{20}	3×10^{-8} to 10^{-12}
7. γ-rays	10^{18} to 10^{22}	3×10^{-10} to 3×10^{-14}

The infra-red region covers a frequency range 3×10^{11} Hz to 4.3×10^{14} Hz. In terms of wavelength, this range corresponds to 0.1 cm to 7×10^{-5} cm The wavelength of this region cannot help in vision. These waves can produce heat effect but do not have any chemical effect. The infra-red wavelengths can be detected by this property. Ultra-violet rays can produce *fluorescence* and *phosphorescence* effects. In both the cases, a substance absorbs ultra-violet rays and emits light of a longer wavelength in the visible region. In fluorescence light, emission stops as soon as the exciting light is cut off, but in phosphorescence light emission continues for some time even after the exciting light is cut off The common example ot fluorescent sources are fluorescent tube lamps. It is a long glass-tube of about 0.6m or 1.2m length. The tube is filled with a mixture of argon and nitrogen with traces of mercury vapour at low pressure. The inner wall of the tube is coated with fluorescent materials When electricity flows through the gases in the tube with the help of two electrodes placed at the two ends of the tube, the ultra-violet rays are generated. These ultra-violet rays strike the fluorescent materials on the wall of the tube and are converted into visible light. In a fluorescent tube, about 60 per cent electrical energy is converted into light against 20 per cent in an ordinary electric bulb.

EXERCISES

1. What is a wave ? How does the motion of the particles of a medium differ from that of a wave through it ?
2. Distinguish between transverse and longitudinal waves When the wire of a sitar is plucked, what type of waves will be produced in (a) the wire; (b) air ?

   You are given solid, liquid and gaseous media. What are the types of waves that can be produced in each of them ?
3. Explain. (a) compression; (b) rarefaction; (c) frequency; (d) time period; and (e) wavelength. Deduce the relation:

   velocity of a waves = frequency × wavelength.
4. How waves are represented graphically? Draw a diagram. Show from the diagram (a) amplitude; and (b) wavelength.
5. In a ripple tank, 10 full ripples are produced per second. The distance between a trough and a crest is 10 cm. Find (a) the frequency; (b) the wavelength; and (c) the velocity of the ripples.
6. Longitudinal waves travel in a coiled spring at the rate of 2 m/s. If the distance between the two successive compressions is 10 cm, find the frequency of the wave motion.
7. Write down the velocity of sound in air, water and iron. The steam of a railway engine is seen first and the whistle is heard a little later. Why ?

   If a thunder is heard 3 seconds after the lightning is seen, how far was the lightning from the observer ?
8. What is the audible range of a man. What are ultrasonics. What are ultra-violet and infra-red rays. In what way do they differ from one another ?

   If the frequency of a radio wave is 670k Hz, find the wavelength of the wave.
9. What are frequencies of the following waves:

   (a) radio waves; (b) gamma rays; (c) ultra-violet rays; (d) X-rays.

Chapter 20

Reflection and Refraction of Light

20.1 Spherical mirrors

Do you know what types of mirrors are used in torches ? You may doubt them to be spherical mirrors. Actually, they are not perfectly spherical. Such curved mirrors which are not perfectly spherical are called *paraboloid mirrors* (Fig 20.1a).

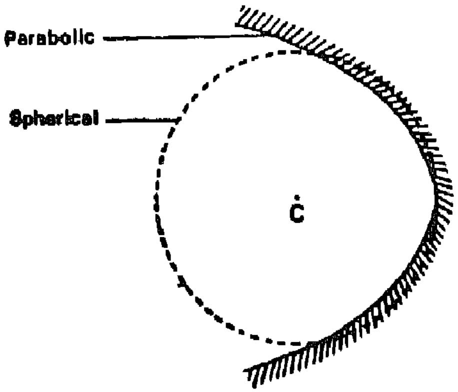


Fig. 20.1a Non-spherical nature of a paraboloid mirror

Even a large spherical mirror does not focus all the incident rays (outer as well as inner) to a single point (Fig. 20.1b). This focussing defect is called *spherical aberation.* The paraboloid mirrors, on the other hand, do not have such a defect (Fig. 20.1c). If a light source is properly placed close to such a mirror, an intense parallel beam of light can be produced (Fig. 20.1d). Because

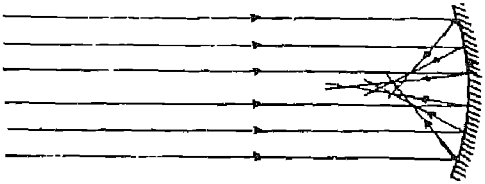


Fig. 20.1b Focussing defect in a spherical mirror

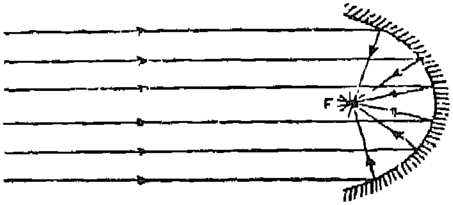


Fig. 20.1c No focussing defect in a paraboloid mirror

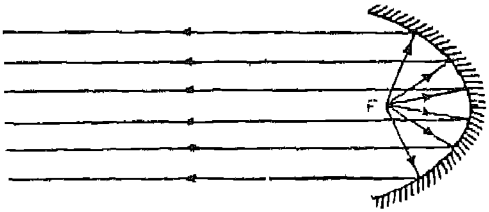


Fig. 20.1d Intense parallel beam produced by a paraboloid mirror

of this characteristic, the paraboloid mirrors are used in flashlights, searchlights, floodlights, automobile headlights, etc.

Though we have learnt about spherical mirrors in the earlier classes, we will now study more about them in this chapter Before doing so, can you say whether the laws of reflection holding good in the case of plane mirrors are also equally applicable in the case of spherical mirrors ? It is to be noted here that there is only one set of laws of reflection of light for all kinds of reflecting surfaces. It does not matter whether the reflection is taking place at a plane surface or a curved surface. Let us now find out the relation between the focal length and the radius of curvatures of a spherical mirror.

20.1—1 Relation between f and R of a spherical mirror

For convenience, consider two incident rays, TM (parallel to the principal axis) and CO (coincident with the principal axis), coming from a far-off source and falling on a concave mirror (Fig. 20.2). The former is reflected along MF and the latter along OC to form an image at the focus F. According to the laws of reflection,

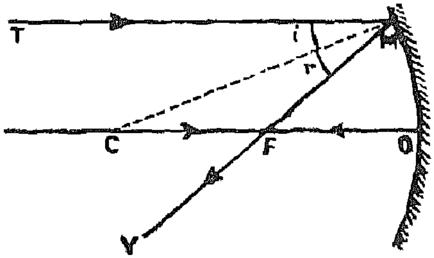


Fig. 20.2 Reflection of a parallel beam of light by a concave mirror

$\angle i = \angle r$

Also, $\angle i = \angle MCF$ (since these are alternate angles)

Hence, $\angle MCF = \angle r$

Therefore, $CF = MF$

While dealing with the reflection by spherical mirror, the angle subtended by the periphery of the mirror at its centre of curvature is also taken into account. This angle is known as the *aperture* of a spherical mirror. For a small aperture, the point M is very near to the point O.

Therefore,

$$MF = OF$$

Hence, $OF = FC$

i.e., the focal length $= \frac{1}{2}$ radius of curvature

or $f = \frac{1}{2}R$

The same can also be proved for convex mirrors. Try to do it with the help of Fig. 20.3.

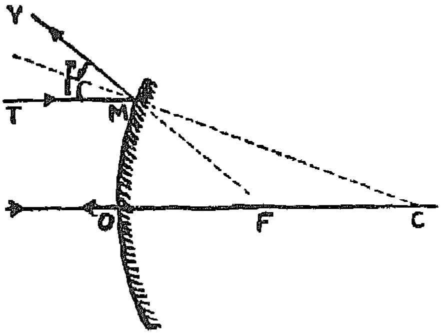


Fig. 20.3 Reflection of a parallel beam of light by a convex mirror

20.1—2 Concave mirror

It is very interesting to observe in the case of a concave mirror that if the object placed in front of the mirror is moved towards or away from it, the position as well as the size of the image also change. Let us study it in more detail by doing the following experiments.

Place an object in front of the mirror beyond its centre of curvature. The image is formed between its focus and the centre of curvature and is diminished, real and inverted (Fig. 20.4). If the object is now moved towards the mirror, the image moves towards the centre of curvature.

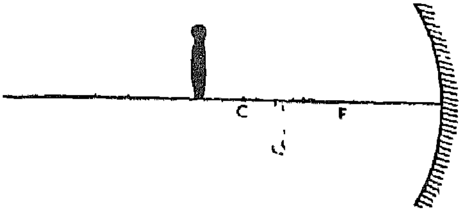


Fig. 20.4 Image formed by a concave mirror when the object is beyond C

In case the object moves past the centre of curvature, the image is formed away from the centre of curvature and is magnified real and inverted (Fig. 20.5).

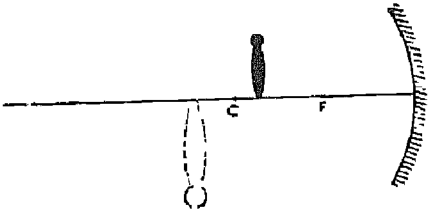


Fig. 20.5 Image formed by a concave mirror when the object is between C and F

If the object is placed exactly at the centre of curvature, where would the mage be formed and what would be its size and nature? You might like to find it out yourself. Try it and note down your findings.

If the object is further moved towards the mirror so that it is now between the focus and the pole of the mirror, the image is formed behind the mirror. It is magnified, erect and virtual (Fig. 20.6).

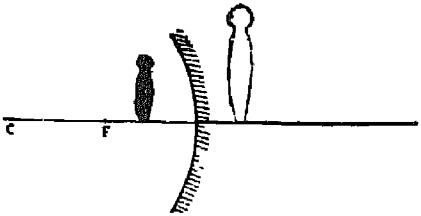


Fig. 20 6 Image formed by a concave mirror when the object is within F

If the object is at the focus of the mirror, where is the image formed? Find out its size and nature also with the help of a ray diagram.

There appears some relation between the object distance, the image distance and the focal length of the mirror. It can be found out with the ehlp of a ray diagram. But before doing so, we must be aware of the sign convention for measuring the distance. There are different conventions in this regard. However, one of them to be followed by us is given on the following page.

The sign convention

1. All distances are measured from the pole of the mirror as the origin.
2. The distances measured in the same direction as that of the incident light are taken as positive.
3. The distances measured against the direction of the incident light are taken as negative.

In this book, we shall always draw the incident ray of light as going from left to right, as shown in the ray diagrams. In such a case, the distance measured from the pole to the right is positive and to the left, negative This agrees with the familiar convention of signs used in Cartesian coordinates, namely, the distances measured to the right of the origin are positive and those measured to the left of the origin are negative. The sign convention given above thus becomes easy to remember when expressed in this way.

On the basis of this convention, the focal length of a convex mirror is positive and that of a concave mirror, negative

20.1—3 The mirror formula

Now, let us derive the relation between the object distance, the image distance and the focal length of a mirror.

For this, consider Fig. 20.7 where AB and A'B' are the lengths of the object and the image, respectively. Measured from the pole O of the mirror, the object distance is taken as u and the image distance as v. Since the two triangles ABC and A'B'C are similar, therefore,

$$\frac{AB}{A'B'}=\frac{BC}{B'C}=\frac{OB-OC}{OC-OB'} \qquad \ldots(20\text{—}1)$$

The triangles MQF and A'B'F are also similar. Therefore,

$$\frac{MQ}{A'B'}=\frac{QF}{FB'}$$

or $$\frac{AB}{A'B'}=\frac{QF}{OB'-OF} \qquad \ldots(20\text{—}2)$$

(since MQ is equal to AB)

Now, QF is a little shorter than OF. But if we are dealing with mirrors of a small aperture, we may assume, to a good approximation, that

$QF=OF=f$.

Equating the right-hand side of the two equations (20—1) and (20—2), we get,

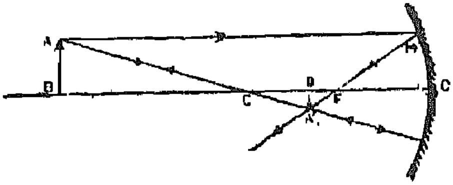


Fig. 20.7 A ray diagram showing the image formation in a concave mirror

$$\frac{OB-OC}{OC-OB'}=\frac{OF}{OB'-OF} \qquad \ldots(20\text{—}3)$$

or $$\frac{-u-(-2f)}{-2f-(-v)}=\frac{-f}{-v-(-f)}$$

or $$\frac{-u+2f}{-2f+v}=\frac{-f}{-v+f}$$

By cross-multiplication, we get,

$$2f^2-vf=uv-uf-2vf+2f^2,$$

or $uf+vf=uv.$

Dividing throughout by uvf, we get

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \qquad \ldots(20\text{—}4)$$

This formula expresses the relation between the object distance, the image distance and the focal length of a concave mirror.

20.1—4 Determination of the focal length of a concave mirror

When an object is placed in front of a concave mirror at a distance R (the radius of curvature), the image is also formed there in the same vertical plane (i.e., at an equal distance from the concave mirror). With the help of this knowledge, we may determine the radius of curvature quite accurately and derive the value of its focal length with the help of the relation, $f=\frac{R}{2}$. Now, try to find out the focal length of a concave mirror using the above knowledge.

20.1—5 Convex mirror

In the case of a convex mirror, we find that the image of an object is always formed behind the mirror, irrespective of the placement of the object in front of the mirror (Fig. 20.8). The image in this case is always diminished,

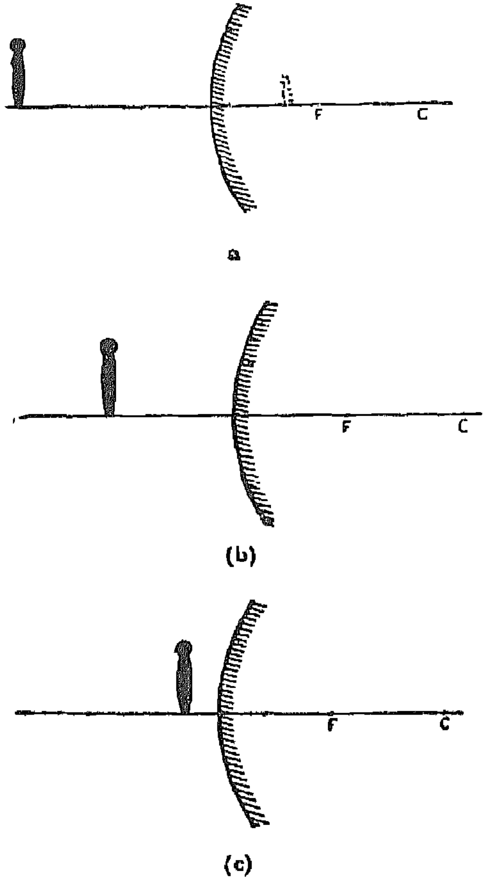


Fig. 20.8 Image formed by a convex mirror for different positions of the object

erect and virtual. Check these findings with the help of ray diagrams. Here also, the object distance, the image distance and the focal length are related in the same way as in the case of a concave mirror, i.e.,

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

Try to prove it yourself with the help of a ray diagram. But while doing so, you must keep the sign convention in mind.

20.1—6 Magnification in spherical mirrors

The image of an object formed by a spherical mirror, in general, is of a size different from that of the object. In some cases, it is smaller than the object and in others, it is larger. The ratio of the height of the image to the height of the object is called *magnification*, and is usually represented by the symbol M.

From the equation (20—2) given earlier, we have

$$M\ \frac{A'B'}{AB}\quad\frac{OB'-OF}{OF}=\frac{-v-(-f)}{-f}=\frac{v}{f}-1 \qquad ..\ (20-5)$$

Magnification can also be expressed as the ratio of the image distance to the object distance. It can be seen by multiplying both sides of the equation (20—4) by v that,

$$\frac{v}{f}-1=\frac{v}{u}$$

EXAMPLE 1

An object is placed 9 cm from a convex mirror of focal length 18 cm. Find the position and nature of the image.

Here, $u=-9$ cm

$f=+18$ cm (convex mirror)

Substituting these values in the mirror formula, we get

$$\frac{1}{v}+\frac{1}{-9}=\frac{1}{18}$$

$$\text{or}\qquad \frac{1}{v}=\frac{1}{18}+\frac{1}{9}=\frac{1+2}{18}=\frac{3}{18}$$

$$\text{or}\qquad v=+6\text{ cm}$$

The positive value of v indicates that the image is formed behind the mirror and is virtual.

EXAMPLE 2

An object is placed 60 cm away from a concave mirror of focal length 20 cm Find the position and nature of the image formed.

Here, $u = -60$ cm

$f = -20$ cm

$$\frac{1}{v} + \frac{1}{-60} = \frac{1}{-20}$$

$$\text{or} \quad \frac{1}{v} = \frac{1}{60} - \frac{1}{20} = \frac{1-3}{60} = \frac{-2}{60} = \frac{-1}{30}$$

$v = -30$ cm

The negative value of v means that the image is on the same side of the object. In other words, a real image is formed 30 cm from the mirror on the same side of the object.

EXAMPLE 3

A concave mirror produces a real image 2 cm high of an object 0.5 cm high placed 10 cm from the mirror. Find the position of the image and the focal length of the mirror.

Using the magnification formula, $M = \frac{v}{u}$ we get, $\frac{2 \text{ cm}}{0.5 \text{ cm}} = \frac{v}{-10 \text{ cm}}$

$v = -40$ cm

Now, substituting the values of u and v in the formula (20—4), we finally get

$$\frac{1}{-40} + \frac{1}{-10} = \frac{1}{f}$$

$$\text{or} \quad \frac{-1-4}{40} = \frac{1}{f}$$

$f = -8$ cm

20.1—7 Application of sphercial mirrors

CONCAVE MIRRORS

1. Concave mirrors are used as reflectors in the headlights of cars, in searchlight equipment, etc., where the source of light is placed at the

focus of the mirror and a parallel beam of light is produced by reflection.

2. Concave mirrors are used by dentists to concentrate light on the tooth to be examined.
3. Shaving mirrors, which give an enlarged, erect image of the face, are slightly concave. When the face is closer than the principal focus, a magnified, erect image is formed behind such mirrors.

CONVEX MIRRORS

Convex mirrors are used in automobiles for the benefit of drivers because of the following reasons :

(i) A convex mirror always produces an erect image.
(ii) Such mirrors have a very wide field of view and, therefore, the images of many objects of the traffic behind can be easily seen.

20.2 Refraction at plane surfaces

The apparent bending of a stick partly immersed in water and the apparent loss of depth in the case of water in a tank are due to the phenomenon of refraction. Let us now study more about this phenomenon.

20.2—1 Laws of refraction

In the study of reflection, we observed that the incident ray, the reflected ray and the normal to the reflecting surface all lie in one plane. Does a similar law hold good for refraction also ? Let us perform the following experiments to investigate it.

A plane sheet of white plastic is immersed in a tank of water (Fig. 20.9). When it is held in such a way that the incident and refracted beams just graze along the surface of the sheet, it is observed that the plane of the sheet is vertical, i.e., perpendicular to the water surface. This shows that when the incident and refracted beams lie in the plane of the sheet, the normal to the water surface also lies in the same plane. If we repeat the experiment by sending the incident light in different angles, we always find the plastic sheet must be held perpendicular to the water surface to have both the rays, incident and refracted, in its plane. We, therefore, conclude that the *incident ray, the refracted ray and the normal to the surface all lie in the same plane*. This is called *the first law of refraction*.

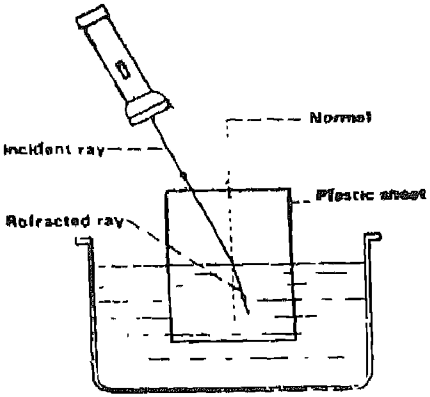


Fig. 20.9 An arrangement to show the first law of refraction of light

In the case of reflection of light, the angle of reflection is equal to the angle of incidence. What is the relation between the angle of incidence and the angle of refraction ? These are certainly not equal. Let us find out the exact relation. Fig. 20.10 shows an experimental arrangement for the same.

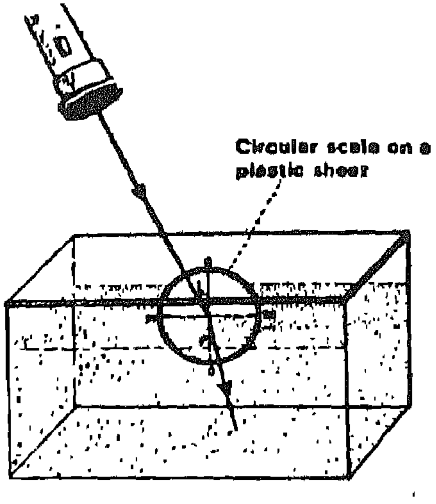


Fig. 20.10 An arrangement to show the second law of refraction of light

A circular scale graduated in degrees is mounted on a plastic sheet. The sheet is immersed vertically in water as before, so that the incident and refracted beams just graze along its surface, and, in addition, the centre of the circular scale is made to coincide with the point where the incident ray strikes the surface of the water. The angles of incidence and refraction can now be measured on the circular scale.

When the incident beam strikes the water surface normally, i.e., when the angle of incidence is zero, it is found that the angle of refraction is also zero The refracted beam goes straight through without bending. As the angle of incidence (i) increases, the angle of refraction (r) also increases. Find the values of sin i and sin r in each case and obtain their ratio. It is seen that for a given pair of media, sin i/sin r is constant for all angles of incidence, so long as we use a particular colour of light. When the colour of light is changed, the value of this ratio also changes even for a particular pair of media. The value of sin i/sin r also varies from one pair of media to the other. For example, this value for the pair of air and carbon disulphide is 1.63; for that of air and glycerine, it is 1.47, and for air and water, it is 1.33. It must be remembered that, by convention, this numerical value known as the *refractive index* of a material always refers to a particular colour of light passing from a vacuum into a medium. However, in practice, air takes the place of the vacuum.

It was Descartes in 1637 who first stated the above relationship between the angles of incidence and refraction in its modern form. However, it is known as *Snell's law* in the honour of Willebred Snell Van Royen who discovered in 1631 an approximate relationship in the form of the direct ratio of i and r. Snell's law is also called the *second law of refraction*. Thus, the second law of refraction states that *in the case of a particular colour of light, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given pair of media.*

In the mathematical form, the above law can be expressed as

$$\frac{\sin i}{\sin r} = \text{constant}$$

20.2—2 Refractive index

The ratio sin i/sin r in the case of vacuum and a given medium is called the *refractive index* of the medium. The value of the refractive index of a particular substance is an important property of the substance, like its density or boiling point. It may even be used to identify the substance. The symbol used for the refractive index is *n*.

The values of the refractive index for a few substances are given in Table 20.1.

TABLE 20.1

State of substance	Substance	Refractive index (n)
Liquids	Water	1.33
	Ethyl Alcohol	1.36
	Olive oil	1.47
Solids	Ice	1.31
	Glass	1.5—1.9
	Diamond	2.42

The refractive index of glass depends on its chemical composition and, therefore, its refractive index varies from 1.5 to 1.9.

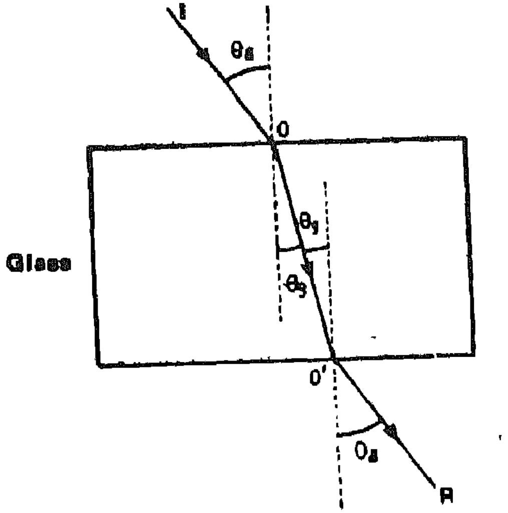


Fig 20.11 Refraction of light through a glass-slab

20.2—3 Refraction through a glass-slab

Next, let us consider the case of light refracted through a rectangular glass-slab as shown in Fig. 20.11. The incident ray IO strikes the first face obliquely and gets bent towards the normal when it enters the glass. If θ_a and θ_g are the angles of incidence and refraction, respectively, we have, by Snell's law :

$$\frac{\sin\ \theta_a}{\sin\ \theta_g}=n_g$$

where n_g is the refractive index of the glass with respect to the air. The ray strikes the second glass face, and when it enters the air it gets deviated from the normal. Experiments show the emergent ray NM leaving the glass is exactly parallel to the incident ray IO. Since the two glass faces are parallel, the angle which the ray OO′ makes with the normal to the second face is also θ_g. Since the two normals are parallel and I O and O′R are also parallel, the angle of incidence and the angle of emergence are also equal. Therefore, the refraction of light from the air to the glass is exactly opposite to the refraction from the glass to the air.

So far as the refraction from the glass to the air is concerned, the angles of incidence and refraction, respectively, are θ_g and θ_a. Hence,

$$\frac{\sin\ \theta_g}{\sin\ \theta_a}=\frac{1}{n_g}$$

The refractive index in this case is the reciprocal of the refractive index for light going from the air to the glass. Thus, we arrive at the important result that the refractive indices for light going from the first medium to the second, and that for light going from the second medium to the first are reciprocal to each other.

Refraction through a combination of media

We can now predict the direction of propagation of light through a combination of refracting media. Suppose, there is a layer of air between two parallel surfaces of the glass and water (Fig. 20.12) and a ray is incident at an angle θ_g on the glass side of the common surface between the glass and air.

As the light leaves the glass, it goes into the air at an angle θ_a such that

$$\frac{\sin\ \theta_g}{\sin\ \theta_a}=\frac{1}{n_g}$$

$\sin \theta_a = n_g \sin \theta_g$

The ray next enters the water and proceeds at an angle θ_w such that

$\sin \theta_a = n_w \sin \theta_w$

Thus, by knowing the refractive index of the medium and the angle of incidence, we can know the direction of propagation of the ray in the second medium.

20.2—4 *Refraction through a prism*

We know that when a ray of light passes through a plane parallel block of glass, the emergent ray is always parallel to the incident ray. If the two faces of the block are inclined, the emergrent ray no longer remains parallel to the incident ray. In such case, we say that the ray of light has been deviated by such a block (Fig. 20.13).

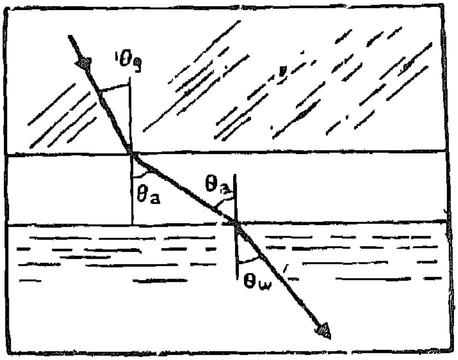


Fig. 20 12 Refraction of light through a combination of media

A block of glass whose two opposite faces are not parallel is called a *prism*. The angle between the two opposite faces is the angle of the prism. Thus, we see that a prism deviates a ray of light. If the angle between the two faces is greater, the deviation will also be greater. It is also found that if a prism is made of glass of a higher refractive index, the deviation becomes greater. In other words, the deviation also depends on the refractive index of the prism. Hence, a flint glass prism deviates a ray of light more than a crown glass prism of the same angle. It is also interesting to note that if a beam of sunlight is

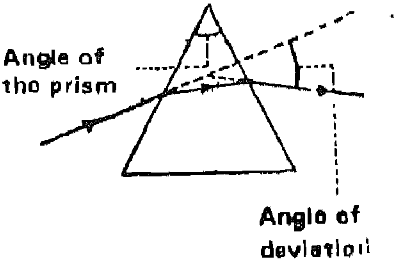


Fig. 20.13 Refraction through a prism

passed through a prism, we get a coloured band (spectrum), instead of an emergent white beam of light. The coloured band is formed due to different colours being deviated differently by the prism (Fig. 20.14). The red is deviated least and the violet most. In other words, the light of a longer wavelength is deviated less and that of a smaller wavelength, more. Such *splitting of a beam of light into its different omponents while passing through a medium is* called the *dispersion of light.*

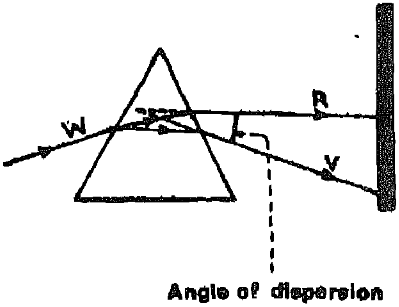


Fig. 20.14 Dispersion of white light passing through a prism

In view of the spectrum formation referred to above, can the white light of the sun be considered to be a mixture of different colours ?

To find the answer, let the spectrum fall upon a hole in a screen so that only red colour comes through it (Fig. 20.15). Place another prism on the other side of the screen so that the red coloured ray passes through it. What do you observe ? The red colour did not disperse into other colours after passing

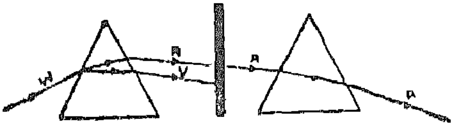


Fig. 20.15 An arrangement to show that white light is a mixture of colours

through the second prism. The same thing is observed with other colours (green, blue, etc.) in the spectrum. From the above experiment, we conclude that white light is really a mixture of the constituent colours of the spectrum.

Do you know why are the rays of different colours deviated differently by the prism ? The fact is that the light of different colours (different wavelengths) travel at different speeds within the glass and, thus, they suffer different deviations producing a spectrum.

20.2—5 Are some observations due to refraction ?

The lengthening of time between sunrise and sunset and the twinkling of stars can be explained with the help of refraction.

The apparent time of sunrise and sunset

When the sun's rays enter the atmosphere from the region of almost perfect vacuum, they get refracted. The deviation will be the greatest when the rays strike the surface of the atmosphere at almost grazing incidence, i.e., when the sun is at the horizon. Owing to the refraction, the rays get bent downward. Hence, the sun appears higher up in the sky than it really is. The result is that the sun is visible to us even when geometrically it is slightly below the horizon (Fig. 20.16). Because of this, the time between sunrise and sunset is lengthened by about four minutes.

Twinkling of stars

Stars appear to fluctuate in brightness. Sometimes, the fluctuation in brightness is accompanied by a change in their colour also, when observed through a telescope. These fluctuations are partly due to the frequent changes in the refractive index of the atmosphere.

The atmosphere of the earth is never still, there being always currents of both hot and cold air at all heights. Thus, the rays from the stars get bent from

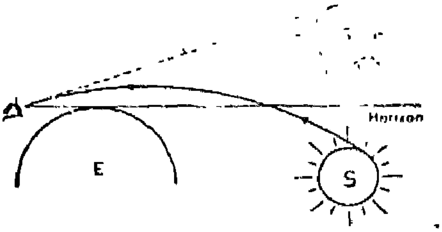


Fig. 20.16 The position of the sun during sunrise and sunset

layer to layer by the time they reach the observer Sometimes, a sudden variation in the intervening atmosphere reflects the rays to one side so that for a very short time the light is partially (or sometimes even wholly) cut off from the observer. This gives rise to the twinkling of stars.

Now the question arises as to why the moon and the planets do not twinkle like the star. The reason for this is quite simple. We know that the moon and the planets are very near the earth as compared to the stars. As a result of this, a star can be considered almost as a point source of light while the moon or a planet has to be considered as an extended source. So, the angle subtended by the disc of the moon or a planet is large in contrast to that subtended by a star. Hence, the slight deviations in the rays from the moon or the planet caused by the atmospheric fluctuations are not noticeable.

20.2—6 Total internal reflection

A curious phenomenon which you might have noticed when travelling on a concrete asphalt road on a hot summer day is that the road at a distance appears to be covered with water. The phenomenon is best observed when the eye is nearly on a level with the road e. g. just as the car reaches the summit of a hill, one can see even the reflection of the sky or any brightly coloured object at a distance. But as one approaches the region where the water appears to be, one realises that in fact there is no water at all and that it was just an illusion. This phenomenon is known as *mirage*. The scorched sands of a desert show the mirage in a most striking fashion and you must have heard stories of desert travellers who have been deceived by this optical illusion. Do you know what causes this illusion ? Let us perform the following experiment to understand its cause. Place a source of light on one side near the bottom of a tank of water and our eyes on the other side as shown in Fig. 20.17. Let the light fall at different angles of incidence.

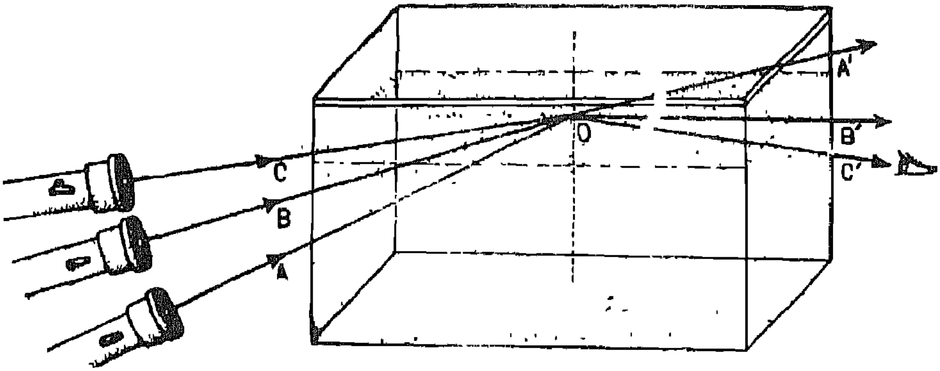


Fig. 20 17 An arrangement to show total internal reflection of light

The ray AO gets refracted along OA′, the angle of refraction being greater than the angle of incidence. The ray BO gets refracted along the surface of the water so that the angle of refraction is 90°. The corresponding angle of incidence is called the *critical angle* of incidence. In other words, *the critical angle is the angle of incidence for which the angle of refraction is 90°, i.e., when the refracted ray grazes along the surface of separation when a ray of light goes from a denser to a rarer medium.* Can you even get the stage of the critical angle of incidence in the case of light passing through a rarer to a denser medium ?

If the angle of incidence in the denser medium is greater (like that of the ray CO) than the critical angle, there is no refraction into the rarer medium, but only reflection in the denser medium. This phenomenon is called *the total internal reflection.* Here, the laws of reflection are obeyed. It is to be remembered here that the phenomenon of total internal reflection occurs only in the case of light going from a denser to a rarer medium.

How is the mirage formed ?

Let us now understand how the mirage is caused. When the ground is strongly heated by the sun, the layers of air in contact with it become hotter than those at a slightly greater height. The density of the hot air being less, its refractive index becomes lower than that of the layers above. Hence, such a condition favours the total internal reflection of light within the atmosphere as shown in Fig. 20.18.

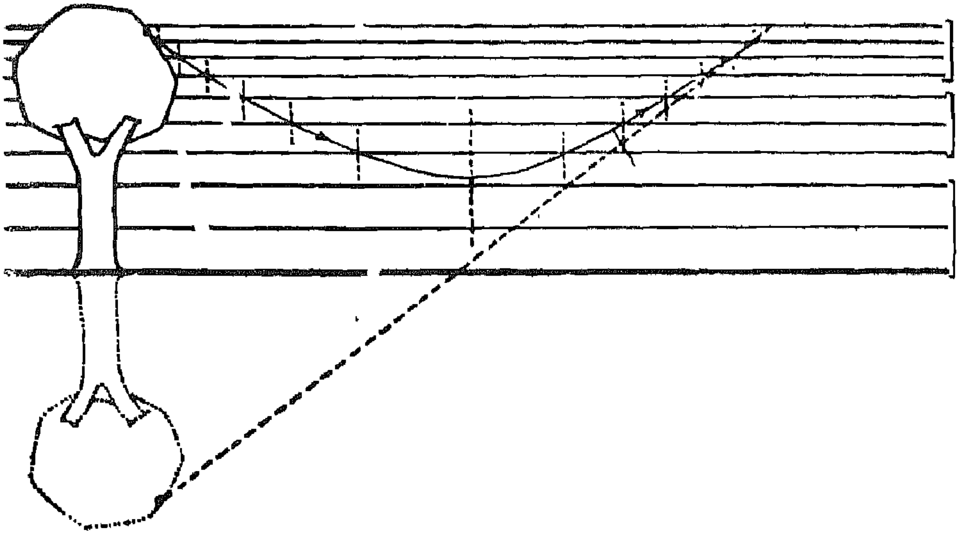


Fig. 20.18 Mirage formation

A ray AO gets totally internally reflected at the layer of hot air, provided its angle of incidence is sufficiently large. Since the angle of incidence has to be large, the mirage is usually seen only at a distance. In special circumstances, it can be seen at close quarters, but only if the line of sight is nearly on a level with the ground.

In reality, however, one cannot speak of a sharply defined layer of the hot air separated from the cold air above it. There is a gradual transition from the hot to the cold air. Thus, instead of the ray being sharply reflected back, it takes a curved path.

20 3 Refraction at spherical surfaces

With the help of our eyes, we see most of the objects around us. But can we see too small or too far-away objects with the help of our eyes ? Lenses are used to overcome such situations. They are also used in our spectacles to help our eyes when they develop some defects in them. In view of their usefulness, it is worthwhile, therefore, to learn about them in some detail.

20.3—1 Lenses

A lens is a piece of transparent material bound by two surfaces, one of which at least is curved. Though the lenses which you have come across are made of glass, they are also made of other transparent materials like plastic, quartz, etc. Lenses may be broadly classified into two groups : *convex* and *concave*. Different types of convex and concave lenses have been shown in Fig. 20.19.

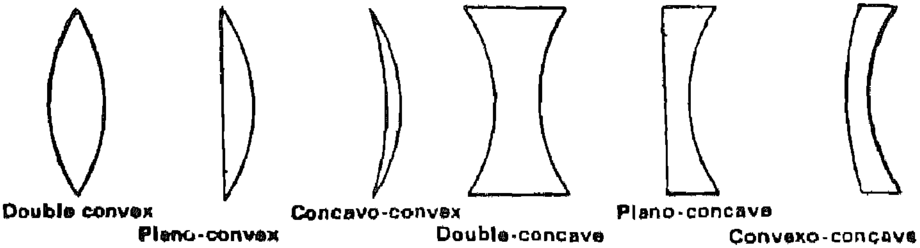


Fig. 20.19 Types of lenses

Lenses whose surfaces are portions of spheres are called *spherical* lenses and those with cylinderical surfaces are called *cylinderical* lenses.

The centre of the sphere or cylinder, of which a surface of a lens is part, is called the *centre of curvature*. In case, if one of the surfaces is flat, its centre of curvature is considered to be at infinity. Thus, each lens has two centres of curvature and hence two radii of curvature as shown in Fig. 20.20. It should, however, be noted that both the radii of curvature in a lens need not necessarily be always equal.

The straight line passing through both the centres of curvature is called the *principal axis* of the lens. In our further discussions, we will consider the case of spherical lenses only.

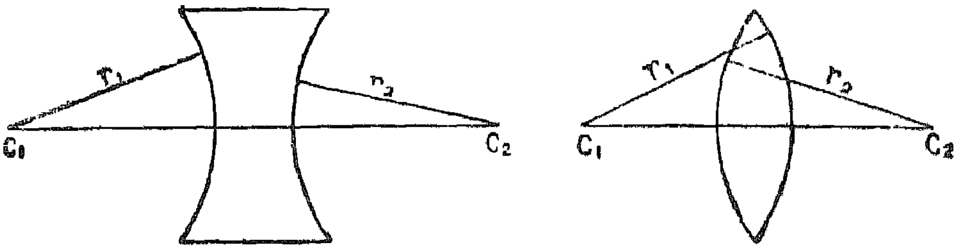


Fig 20.20 Centres and radii of curvature in lenses

Convex lens

A convex lens is analogous to two prisms placed with their bases on the two opposite faces of a rectangular glass-slab as shown in Fig. 20.21.

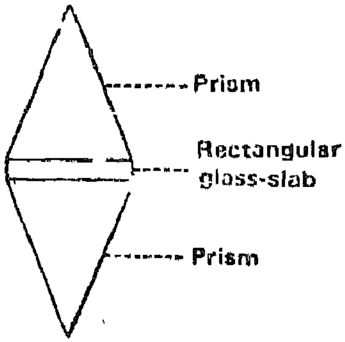


Fig. 20.21 Convex lens as a combination of two prisms and a rectangular slab

Since in the case of a prism, the light passing through is bent towards its base, the above arrangement is also capable of converging the light. Because of this converging action, a convex lens is also called a *converging* lens.

Concave lens

A concave lens is analogous to two prisms placed with their vertices on the two opposite faces of a rectangular glass-slab as shown in Fig. 20.22.

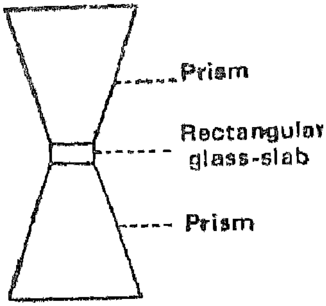


Fig 20.22 Concave lens as a combination of two prisms and a rectangular slab

The above arrangement is capable of diverging the light. Because of this diverging action, a concave lens is also called a *diverging* lens.

Inside a lens, a point is so situated on the principal axis that there is no bending of the light rays if they pass through this point. This point is known as the *optical centre* of the lens.

The point at which rays incident parallel to the principal axis of a lens converge or appear to diverge after refraction through the lens is known as its *focus* and the distance of the focus from the lens is called the *focal length* of the lens. Since there are two faces of a lens, each lens has two focii, one on each side (Fig. 20.23).

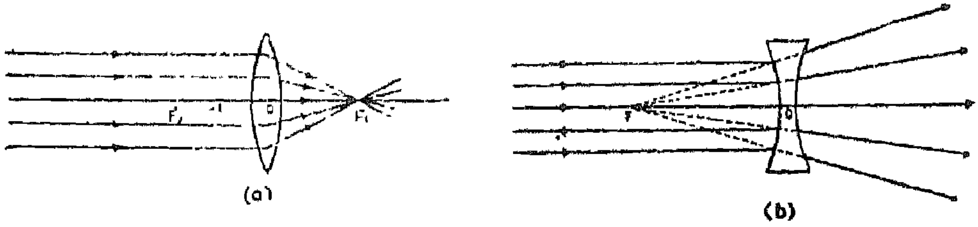


Fig. 20.23 Two focii of a lens

A thicker lens with a sharper curvature has a shorter focal length than a thinner one (Fig. 20.24). In other words, the more converging or diverging a lens is, the shorter is its focal length.

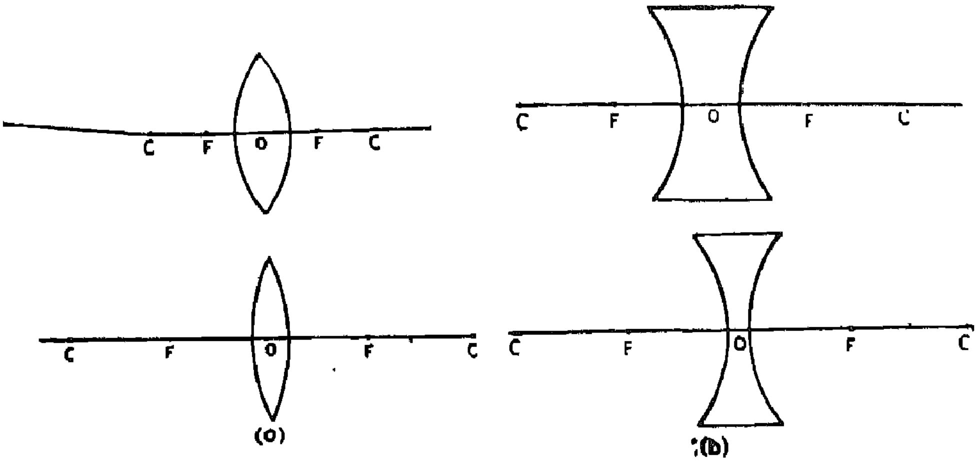


Fig. 20.24 Thick and thin lenses

20.3—2 Power of a lens

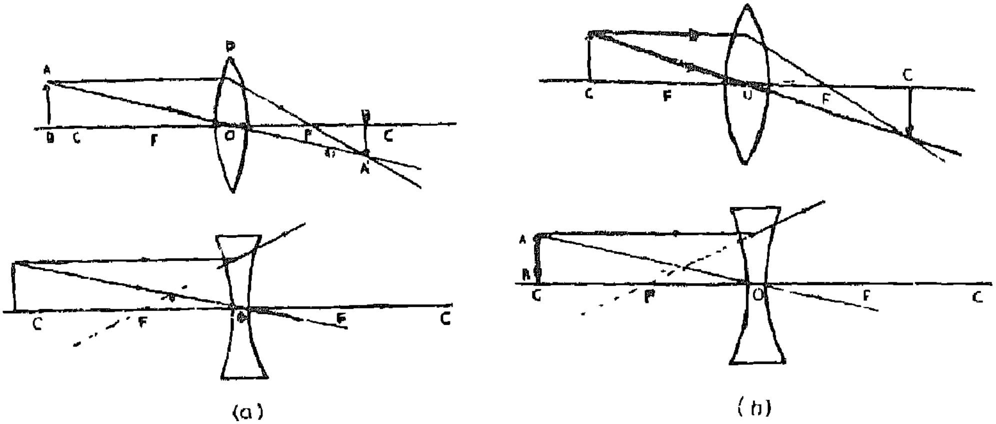
We have just learnt that a thick lens with sharply curved surfaces bends light rays much more than does a thinner lens. The former, therefore, possesses more power (bending power). Since the focal length of the former is smaller than the latter, the power of a lens varies inversely as its focal length. In practice, the power of a lens is expressed as the reciprocal of its focal length. So, if D and f stand for the power and focal length of a lens, respectively, we have

$$D = \frac{1}{f}$$

When f is measured in the unit of *metre*, the resulting unit D is called *dioptre*. Thus, in the S.I. unit, the power of a lens is expressed in the unit of *dioptre*.

Image formation

We shall now study how the location of images formed by a lens is dependent upon the location of an object in front of a lens. For doing so, let us follow the same procedure which was adopted in the case of spherical mirrors.



(a) (b)

Fig. 20.25 A ray diagram showing the image of an object placed (a) beyond 2f, (b) at 2f

Note down the location, size and nature of the images by placing an object at the following locations in front of a convex lens as well as a concave lens : (i) Beyond 2 f, (ii) at 2 f, (iii) between 2 f and *f* (iv) between F and the lens. What are your findings ? The ray diagrams for the cases (i) and (ii) are given in Fig. 20.25a and 20.25b, respectively.

The ray diagrams for the rest of the above cases may also be drawn and the results so obtained may be compared with your findings. Now, can you tell where the image will be formed by a convex lens when the object is placed at (i) infinity and (ii) focus ? Will it be the same in the case of a concave lens ? Find out the answers for the above also, using a ray diagram.

In drawing ray diagrams in the case of lenses, it is convenient to consider only two incident rays : one, parallel to the principal axis, and the other passing through the optical centre.

20.3—3 Relation between the object and the image distance and the focal length of a lens

We have already derived a formula expressing the relation under reference in the case of spherical mirrors. This was done with the help of ray diagrams.

Can you derive a similar formula in the case of lenses ? Let us consider the case of a convex lens first.

The object is represented by AB standing on the principal axis (Fig. 20 26). Its image formed by the lens is A_1B_1. Let the object distance, the image distance and the focal length of the lens be denoted by u, v and f.

Since the triangles ABO and A_1B_1O are similar, we have

$$\frac{A_1B_1}{AB}=\frac{OB_1}{OB} \qquad ...(20-6)$$

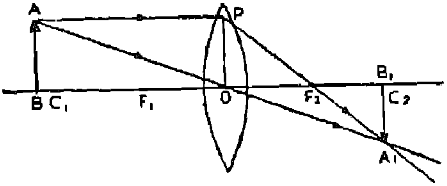


Fig. 20.26 Relation between the object distance and the image distance in a convex lens

$\triangle$s POF_2 and $A_1B_1F_2$ are also similar,

$$\frac{A_1B_1}{PO}=\frac{B_1F_2}{OF_2} \qquad ...(20-7)$$

Since AB=PO, we have, from the equations (20—6) and (20—7),

$$\frac{OB_1}{OB}=\frac{B_1F_2}{OF_2}=\frac{OB_1-OF_2}{OF_2} \qquad ...(20-8)$$

Using the same sign conventions as in the case of spherical mirrors, we get

$$OB=-u$$
$$OB_1=+v$$
$$OF_2=+f$$

Substituting these values in the equation (20—8), we get

$$\frac{v}{-u}=\frac{v-f}{f}$$

or $vf=-uv+uf$

or $uf-vf=uv$

or $\frac{uf-vf}{uvf}=\frac{uv}{uvf}$

or $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ ...(20—9)

Now, using the ray diagram, try yourself to derive the formula similar to the above in the case of a concave lens You will find that the above formula also holds good for a concave lens.

EXAMPLE 1

Find the position and nature of the image of an object 3 cm high and placed 20 cm in front of a convex lens of focal length 12 cm.

We have

$u = -20$ cm

$f = +12$ cm

Substituting these values in the formula (20 – 9), we get

$$\frac{1}{v} - \frac{1}{-20} = \frac{1}{12}$$

or $$\frac{1}{v} = \frac{1}{12} - \frac{1}{20} = \frac{5-3}{60} = \frac{2}{60} = \frac{1}{30}$$

$v = 30$ cm

So, magnification

$$M \quad \frac{v}{u} = \frac{+30}{-20} = -1.5$$

The image is, therefore, real, inverted magnified and at a distance of 30 cm on the other side of the lens.

EXAMPLE 2

An object is placed 4 cm from a concave lens of focal length 12 cm Where is the image formed and what is its magnification ?

We have $u = -4$ cm and $f = -12$ cm

Substituting these values in the lens formula (20—9), we have

$$\frac{1}{v} - \frac{1}{-4} = \frac{1}{-12}$$

or $$\frac{1}{v} = \frac{-1}{12} - \frac{1}{4} = \frac{-1-3}{12} = \frac{-4}{12} = \frac{-1}{3}$$

or $v = -3$ cm

The image is on the same side as the object and is virtual.

The magnification $\frac{v}{u} = \frac{-3}{-4} = 0.75$

—4 *Microscope*

A microscope is an optical instrument used to see very very small objects orming their magnified images at the least distance of distinct vision from eye. There are two types of microscopes : (a) simple, and (b) compound.

Simple microscope

It consists of just a convex lens of small focal length. We know that a ex lens produces an erect and magnified image when the object is placed at tance less than its focal length. This property is made use of in a simple oscope. In other words, a simple microscope is nothing but a magnifying . Fig. 20.27 shows how the magnified virtual image of a small object is ed in the case of a simple microscope.

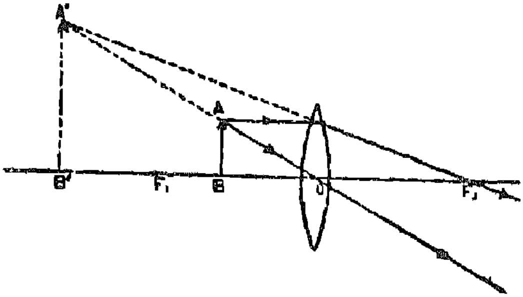


Fig. 20.27 Image formation in a simple microscope

The magnification in the case of a convex lens can be shown to be

$$M = 1 - \frac{v}{f}$$

Now taking the image distance to be equal to 25 cm, the least distance of t vision, the magnification M turns out to be

$$M = 1 - \frac{-25}{f} = 1 + \frac{25}{f}$$

Thus, we see that the magnification increases with the decrease of the focal of the lens. Even if the focal length of a convex lens used is very small, cm, the magnifying power cannot exceed the value of 30. To get higher fication, a compound microscope, therefore, has to be used.

(*b*) *Compound microscope*

It consists of two convex lenses so arranged that the relative position can be changed as desired. One of the lenses is called the *objective* and the other, the *eye-piece*. The objective is of a very short focal length and is placed close to the object. The eye-piece is also of a short focal length and is kept close to the eye The objective forms a real and magnified image A_1B_1 at a point just in front of the eye-piece. The real image so formed by the objective of the microscope becomes the object for the eye-piece. Now, the position of the eye-piece is so adjusted that it lies within its focus The eye-piece, therefore, produces a magnified virtual image

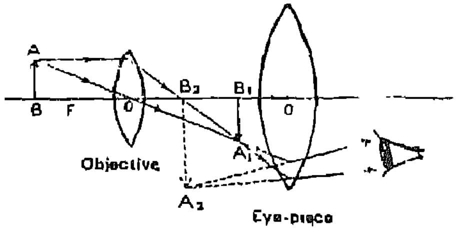


Fig. 20.28 Image formation in a compound microscope

The overall magnification of a compound microscope is given by

$$M = \frac{A_2B_2}{AB} = \frac{A_1B_1}{AB} \times \frac{A_2B_2}{A_1B_1} = M_o \times M_e$$

where M_o = magnifying power of the objective, and

M_e = magnifying power of the eye-piece

Under suitable conditions, the magnifying power of about 2000 can be attained in the case of optical microscopes.

20 3—5 *Telescope*

A telescope is an optical instrument used for surveying distant objects. It consists of two lenses, which are called the *objective* and the *eye-piece*. The focal length and aperture of the objective is much greater than that of the eye-piece.

Astronomical telescope

It consists of two convex lenses, the distance between them being equal to sum of their focal lengths.

When a very distant object, like a star, is viewed, a real image IF is med by the objective in its focal place (Fig. 20.29) This is because the rays

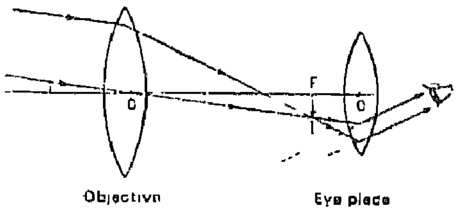


Fig. 20.29 Image formation by an astronomical telescope

reach the telescope from any point of the distant object are practically allel. Each set of parallel rays comes to a focus at a point in the focal plane he objective, so that the image lies in that plane. Now, IF itself acts as the ect for the eye-piece. Since F is also the principal focus of the eye-piece, the ge of IF is formed at infinity. In other words, the rays entering the eye of observer are parallel and these rays are, of course, focussed by the lens of eye to form a clear image on the retina.

ilean telescope

A telescope with a different combination of lenses was devised by Galileo 609. Its objective is a convex lens with a large aperture and a long focal gth. Its eye-piece is a concave lens and is placed within the focal length of objective. The lenses are separated by a distance equal to (f_o-f_e), the erence between their focal lengths. Here f_o and f_e are the focal lengths of the ective and the eye-piece, respectively. The final image is formed at infinity i is erect as shown in Fig. 20.30.

The *magnifying power* of a telescope is defined as the ratio of the angular of the image to the angular size of the object as seen by the unaided eye. en the eye is focussed for parallel rays, the magnifying power is the ratio of e where f_o and f_e are the focal lengths of the objective and the eye-piece, ectively Therefore, to achieve high magnification, the objective should have ng focal length and the eye-piece, a short one.

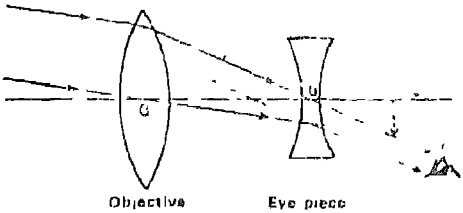


Fig. 20.30 Image formation by a Galilean telescope

20.3—6 Defects of vision

The eye may be considered as an optical instrument similar to a photographic camera Its convex lens forms a small and inverted image of the external objects on the retina. The focal length of this lens is self-adjustable. The farthest point that a normal eye can see is at infinity. The closest point it can see clearly is called the *distance of distinct vision* and is equal to 25 cm.

In a normal eye, when the rays are incident on the eye, its focal length gets so adjusted that the image is formed exactly on the retina. In certain cases when the image is not formed on the retina, the eye is said to be defective, meaning thereby that there is some defect in the eye. There are mainly three kinds of defects (i) short-sightedness (myopia); (ii) long-sightedness (hypermetropia); and (iii) astigmatism.

These defects can be corrected by using suitable lenses. When these lenses are fixed in a frame, we have spectacles. However, it is now possible to fix suitably designed lenses, called *contact lenses*, directly on the eyeball. Let us now study these defects in some detail.

Myopia (short-sightedness)

A person having this defect cannot see distant objects clearly, though he may be able to see distinctly the objects at short distances. This is because the image of a distant object is focussed in front of the retina (Fig. 20.31a). By using a suitable concave lens, this defect can be corrected (Fig 20.31b).

Hypermetropia (long-sightedness)

A long-sighted person can see distinctly the objects at long distances but cannot focus clearly on the near objects. This is because the image of a close object is focussed behind the retina (Fig. 20.32a). This can be counter-acted by using spectacles made of converging lenses (Fig. 20.32b).

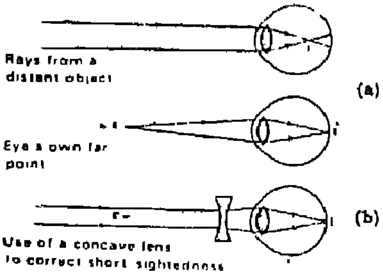

Rays from a distant object
(a)
I
Eye's own far point
F
I
(b)
Use of a concave lens to correct short sightedness

Fig. 20.31 Short-sightedness and its remedy

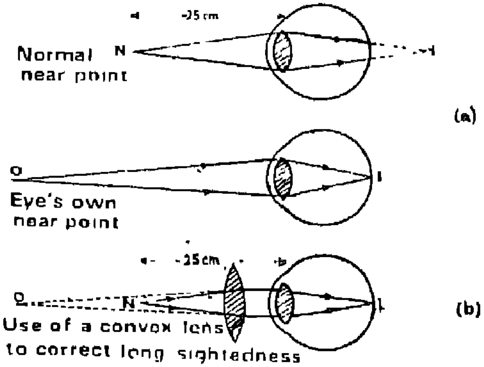


Fig. 20.32 Long-sightedness and its remedy

Astigmatism

This defect is due to the lack of symmetry in the curvature of the eye. As a result, the rays of light entering the eye in different planes are brought to a focus at varying distances from the retina. So, though the object is a point, the shape of the image may be a line, a circle or any other shape except a point. This defect can be corrected by using a cylindrical lens, instead of a spherical lens.

EXERCISES

1. In the case of a concave mirror, match the items in Column B against the items in Column A

COLUMN A	COLUMN B
Position of the object	*Position of the image*
(a) Very far away	(i) Very far away
(b) At C	(ii) Beyond C on the same side as the object
(c) Between F and the pole	(iii) Between F and C
(d) Between F and C	(iv) At C
(e) At F	(v) At F
(f) Beyond C	(vi) On the other side of the mirror, i.e., behind it.

2. Describe the nature of the image formed when the object is placed at a distance of :
   (a) 20 cm from a concave mirror of focal length 10 cm
   (b) 15 cm from a concave mirror of focal length 10 cm
   (c) 8 cm from a concave mirror of focal length 10 cm
   (d) 25 cm from a convex mirror of focal length 20 cm
   (e) 50 cm from a concave mirror of focal length 20 cm
3. You are given three mirrors; one concave, one convex and one plane. How will you identify them without touching the mirrors ?
4. Using a concave mirror of a known focal length, screen and measuring scale in broad daylight, how will you find the height of a tree or a tall building ?
5. The refractive index of olive oil is 1.47. Is this statement scientifically

complete ? Give reasons for your comment.

6. The critical angle of water is 49°. What will happen to the light passing from water to air, if it is incident at an angle of 60° ?
7. The refractive indices of carbon-disulphide and ethyl alcohol are 1.63 and 1.36, respectively. Which of the two is optically denser ?
8. Under what condition does the total internal reflection occur ?
9. The refractive index of one kind of glass is 1.52 and that of another kind is 1.63. Which glass will change the direction of a ray of light more ?
10. Does the critical angle increase with the increase in the value of the refractive index of different substances ? Give reasons
11. When the angle of incidence is equal to the critical angle, the refracted angle is equal to (a) 0°, (b) 45°, (c) [illegible]0°, (d) 180°.
12. With the help of a diagram, explain the following terms: (a) focal length; (b) principal axis; (c) the aperture of a convex lens.
13. What is a lens ? Distinguish between a convex and a concave lens. Explain, with a diagram, why the former is called a converging and the latter, a diverging lens
14. You are given a convex lens, a concave lens and a circular glass-plate. How will you distinguish between them without touching their surfaces ?
15. Match the items in column B against the items in column [illegible] The lens used is convex.

COLUMN A *Position of the object*	COLUMN B *Position of the image*
(a) Very far away	(i) Very far away
(b) Beyond 2f	(ii) On the same side as the object
(c) Between F and the optical centre	(iii) At F
(d) At F	(iv) Between f and 2f
(e) Between f and 2f	(v) Beyond 2f

16 You have two lenses of focal length 5 cm and 30 cm, respectively, and a means of mounting them on a metalic tube. In order to make

a telescope,
(a) which lens would you point towards the object ?
(b) where would you put the second lens ?

17. What part of an astronomical telescope acts as a magnifying glass ? How do we express its magnification ?
18. Explain the principle of a simple microscope and its magnifying ability.

Chapter 21

Carbon

on plays a very important role in our daily life Carbon compounds are d in all living things. The number of compounds containing carbon is over llion and exceeds several times the number of compounds of all the other ents considered together. Carbon compounds have diverse uses in the form od, fuels, fabrics, dyes, drugs, plastics, perfumes, etc. The versatile nature arbon makes it an interesting element. Let us examine the position of on in the periodic table to understand some of its unique properties.

What is the position of carbon in the periodic table ?

Carbon is the first member of group IV-A which includes silicon, ger- nium, tin and lead. All these elements have four electrons in their valence l (Table 21.1).

TABLE 21 1

The electronic configuration and some physical properties of group IV-A elements

ment	*Symbol*	*Atomic No*	*Electronic configuration* K	L	M	N	O	P	*Melting point* (°C)	*Specific gravity*
rbon*	C	6	2	4					>3500	1 8—2 25
icon**	Si	14	2	8	4				1410	2.44(at 25°C)
rmanium	Ge	32	2	8	18	4			937.6	5 32 (at 25°C)
n	Sn	50	2	8	18	18	4		231 9 (grey)	5 75 (grey)
ad	Pb	82	2	8	18	32	18	4	327.3	11 34

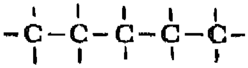
*Amorphous form
**Crystalline form

21.2 What is the unique nature of the carbon atom ?

Its position in the IV-A group which is almost at the centre of a period and the small size of the atom confer on the carbon atom certain unique properties.

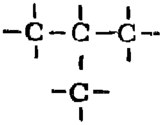
The four valence electrons of the carbon atom make it necessary for the carbon atom to gain four more electrons or to lose its four electrons in order to attain a stable structure Energy considerations show that in chemical reactions it is difficult to take out four valence shell electrons from a carbon atom For the same reason, gaining of four more electrons by a carbon atom is also difficult. So carbon invariably forms covalent compounds

Carbon atoms can link to one another to a great extent through covalent bonds. This explains why there are such a large number of carbon compounds

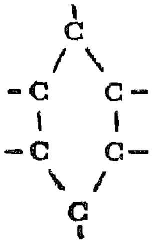


$$-\underset{|}{\overset{|}{C}}-\underset{|}{\overset{|}{C}}-\underset{|}{\overset{|}{C}}-\underset{|}{\overset{|}{C}}-\underset{|}{\overset{|}{C}}-$$

(open-chain)

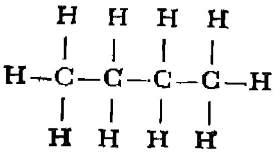


(branched-chain)



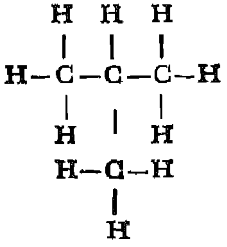
(ring-type)

The ease with which carbon atoms make linkages often results in the formation of two or more entirely different compounds having the same molecular formula. Such compounds are called *isomers*. This is another reason why carbon compounds are so numerous For butane, C_4H_{10}, there are two isomers.



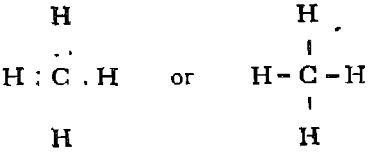
$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H$$

n-butane

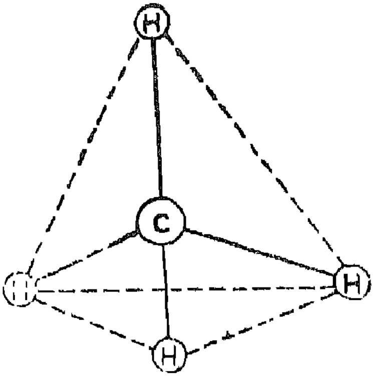


iso-butane

In almost all organic compounds, carbon shows tetravalency. Let us consider the formation of methane The four electrons of the outermost shell of the rbon atom share the four electrons of four atoms of hydrogen to form four ngle covalent bonds.



$$\begin{array}{ccc} & H & \\ H & \overset{\cdot\cdot}{:C\,.} & H \\ & H & \end{array} \quad \text{or} \quad \begin{array}{ccc} & H & \\ & | & \\ H- & C & -H \\ & | & \\ & H & \end{array}$$



The four covalent bonds of this carbon atom in methane are arranged in space in the shape of a *regular tetrahedron* in which hydrogen atoms are at its four vertices.

Let us now study some of the properties of carbon and try to interpret them in terms of the atomic structure just studied.

21 3 What are the allotropic forms of carbon ?

Like the elements oxygen, sulphur and phosphorus, carbon exhibits allotropy. There are only two allotropic forms of carbon, namely, diamond and graphite. Both these are crystalline in shape. The other forms of carbon like charcoal, lamp black, coke, etc , consist of microcrystals of graphite.

21.3—1 What are the properties of diamond ?

Diamond is the hardest natural substance known. Only a diamond can cut another diamond. The great brilliance of diamond is partly due to its high refractive index. This property coupled with the cutting of faces at certain angles brings about the reflection of much of the light that enters the diamond.

Most valued diamonds are those with a bluish tint. The diamond crystals found in nature are generally octahedral (crystals with eight faces). Specific gravity of diamond is about 3.5. Diamond is insoluable in ordinary reagents.

21.3—2 What are the properties of graphite ?

Graphite is nearly as remarkable for its softness as diamond for its hardness. It is easily powdered and has a greasy feel. Its specific gravity is about 2.25. Though it is a non-metal, it is fairly good conductor of electricity.

21.3—3 What are the important uses of other varieties of carbon ?

The other forms of carbon are charcoal, carbon black, coke, etc. These consist of microcrystals of graphite.

Coke is largely used as a fuel as well as a reducing agent in metallurgy and for making electrodes. Carbon black is used in the manufacture of printing ink. Finely divided carbon is mixed with rubber in tyres.

21.4 What is coal ?

Coal is obtained from coal mines. India has rich coal resources. The big coal mines are in Bihar and West Bengal. Coal is also mined in Madhya Pradesh.

How was coal formed ? Geologists tell us that hundreds of thousands years ago, violent changes took place on earth—earthquakes, volcanoes, etc. Huge forests were buried under the surface. The trees and plants became covered with sand, clay and water. They were subjected to high temperature and pressure inside the earth. As a result of the chemical processes, plants changed to coal in nature. This process is called *carbonisation* of plant matter. Depending on the extent of carbonisation we get peat, lignite, bitumen (soft) and anthracite (hard). Coal is thus a complex mixture consisting largely of carbon compounds and free carbon.

21.5 What is the chemical behaviour of carbon ?

The discussion of the allotropic forms of carbon has stressed the differences in their physical properties. Chemically, all forms of carbon behave alike except for small differences such as the rate of reaction with another substance or the amount of heat produced during the reaction. The outstanding chemical behaviour of carbon is its readiness to combine with oxygen, where carbon acts a reducing agent The use of coke in extracting iron from its ore is a good ample.

$$Fe_2O_3(s) + 3C\ (s) \rightarrow 2Fe\ (s) + 3CO\ (g)$$

A similar reduction reaction produces highly useful metal carbides (com-ounds of metals and carbon) which are hard substances with high melting oints. Some carbides are used in rocketry, as nose cones, for re-entry rockets ecause they can withstand very high temperatures produced as the rocket speeds ack into the atmosphere.

When carbon combines with oxygen, much heat is produced.

$$C + O_2 \rightarrow CO_2 + 393.5\ kJ$$

The fuel value of carbon in homes and in industries can be accounted for y the exothermic nature of this reaction.

EXERCISES

1 The following substances or materials contain carbon. Give one or two uses of each. Aspirin, DDT, groundnut oil, soap, kerosene oil, penicillin, polythene, nylon, terylene, cotton, rubber, leather, indigo, vitamin-C, ghee, rayon, gum, wax, petrol, wood, jute, cane sugar, naphthalene balls and grease.

2. Why does carbon form covalent bonds with itself and with other elements ?

3. Why does carbon form such a large number of compounds ?

4 Cyclohexane (C_6H_{12}) has six-membered ring structure. Write the structure of any of its isomers having a five-membered ring.

5. Draw a regular cube Put carbon at the centre Place four hydrogen atoms at the corners such that they are not on the adjacent corners Can you see the tetrahedron so formed ? Show it by broken lines.

6 Is coal being produced inside the earth now ? Explain your answer.

Chapter 22

Compounds of Carbon—Organic Chemistry

Organic chemistry is the chemistry of carbon compounds. It is convenient to study carbon compounds as a separate branch of chemistry because

(a) as we have seen, carbon forms innumerable compounds due to its ability to combine with other carbon atoms giving rise to chains and rings of different sizes and the phenomenon of isomerism which is more commonly observed with carbon compounds (see chapter 21).

(b) carbon compounds exhibit properties which are strikingly different from those of the other elements.

Early chemists noticed that substances isolated from various sources broadly showed two distinct sets of properties and so they divided them into two groups :

(1) substances obtained from air and mineral sources ; like oxygen and nitrogen from air ; salts from sea and river waters ; salts and metal oxides from soils and rocks.

(2) substances isolated from plants, trees, animals and other living creatures ; such as sugar from sugarcane ; oils from seeds ; proteins from eggs, milk and animal tissues.

The latter were called organic compounds because they were in *living organisms* These invariably contained carbon. The former were then called inorganic compounds. The differences between the two were so striking that the early chemists even believed that the formation of organic compounds was influenced by the *life force* (*Vital Force Theory*) present in living bodies. However, by the middle of the last century many organic compounds could be prepared in the laboratory.

Today, we can explain the properties of the organic compounds satisfactorily in terms of modern theories of atomic structure and chemical bonding in a similar way as we do for inorganic compounds.

22.1 What are the distinguishing properties of organic compounds ?

Some of the important properties which distinguish the organic from the inorganic compounds are as follows:

	Inorganic	*Organic*
Solubility in water	Generally soluble	Generally insoluble
in organic liquids	Generally insoluble	Generally soluble
Behaviour on heating	High melting solids Thermally stable	Many are liquids. Solids melt below 300°C, decompose on further heating
Combustibility	Non-inflammable	Inflammable
Composition	Relatively simple ($CaSO_4$, $AlCl_3$)	Complex (Cane sugar, $C_{12}H_{22}O_{11}$)
Isomerism	Very rare	Very common

The above table describes broadly the general features of compounds in each group. There are exceptions, of course, but they are very few.

Although there are hundreds of thousands of organic compounds, their study is not difficult. This is because they can be classified into a few series. In a way, all the organic compounds can be considered to have been derived from hydrocarbons.

22 2 What are hydrocarbons ?

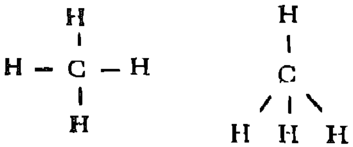
Hydrocarbons are compounds containing carbon and hydrogen only. Examples :

Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}
Benzene	C_6H_6

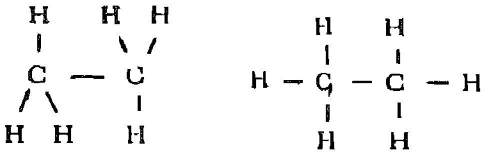
There are mainly three types of hydrocarbons, namely, (i) saturated (ii) unsaturated, and (iii) aromatic.

22.2—1 What are saturated hydrocarbons ?

A hydrocarbon in which the four valencies of each carbon atom are satisfied by single covalent bond is a saturated hydrocarbon. They are called *alkanes*. Methane and ethane are the simplest alkanes The general formula of alkanes is C_nH_{2n+2}.



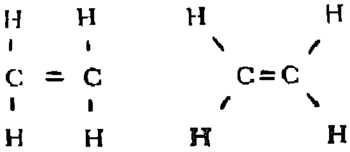
Methane



Ethane

22.2—2 What are unsaturated hydrocarbons ?

Hydrocarbons in which the valencies of at least two adjoining carbon atoms are not fully satisfied by single covalent bonds are known as unsaturated hydrocarbons. In such compounds the carbon atoms satisfy their valencies by forming double or triple bonds between them. So hydrocarbons containing double or triple bonds are unsaturated hydrocarbons.



Ethene (ethylene)

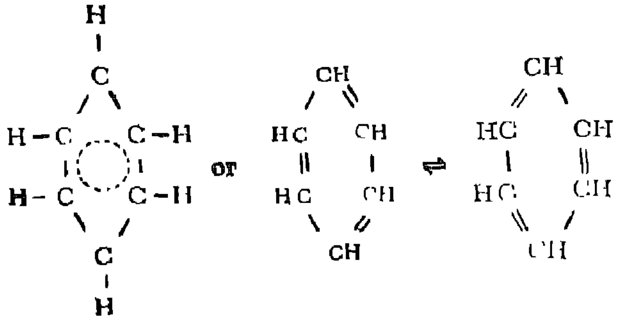
$H-C\equiv C-H$

Ethyne (acetylene)

In ethene, there is a double bond. In ethyne, there is a triple bond. Hydrocarbons containing double bonds are called *alkenes*. Those containing triple bonds are called *alkynes*.

22.2—3 *What are aromatic hydrocarbons ?*

Benzene, C_6H_6, is the simplest aromatic hydrocarbon It has a ring structure



Two other simple aromatic hydrocarbons are toluene (C_7H_8) and naphthalene ($C_{10}H_8$).

22.2—4 *What are the physical properties of the hydrocarbons ?*

Hydrocarbons containing 1—4 carbon atoms are gases; those with 5 – 16 are liquids; higher molecular mass hydrocarbons are solids.

They have characteristic petrol-like odours. They are insoluble in water. They are highly combustible and must be handled with care. The liquid hydrocarbons are good solvents for organic substances.

They are used as fuels, solvents, and as raw materials for making other organic products.

22 2—5 *What are the chemical properties of the hydrocarbons ?*

The saturated hydrocarbons are chemically inert. The unsaturated hydrocarbons are very reactive. The aromatic hydrocarbons are also reactive, but in a different way.

The important reactions of the hydrocarbons are combustion, chlorination, hydrogenation and polymerization.

22.2—6 *What happens when hydrocarbons burn in air ?*

The reaction of hydrocarbons with oxygen is highly exothermic and it results in the complete breakdown of the molecules which catch fire. The products are carbon dioxide and water. The process is called *combustion*.

$$CH_4+2O_2 \rightarrow CO_2+2H_2O+\text{heat}$$
$$CH_2=CH_2+3O_2 \rightarrow 2CO_2+2H_2O+\text{heat}$$
$$2CH\equiv CH+5O_2 \rightarrow 4CO_2+2H_2O+\text{heat}$$
$$2C_6H_6+15O_2 \rightarrow 12CO_2+6H_2O+\text{heat}$$

Fuels like kerosene oil, petrol, diesel oil, etc, are mixtures of alkanes. Domestic gas cylinders, like Indane, contain mainly butane and *iso*-butane. Combustion of acetylene produces a very hot flame used in welding metals (oxy-acetylene flame).

22.2—7 How do hydrocarbons react with chlorine ?

Although the *saturated* hydrocarbons are inert, they react with chlorine in the presence of light or at high temperatures. This is the *substitution* reaction because the hydrogen atoms are substituted by chlorine atoms.

$$CH_4+Cl_2 \rightarrow \underset{\substack{\text{Chloromethane}\\ \text{(methyl chloride)}}}{CH_3Cl}+HCl$$

Further chlorination gives CH_2Cl_2 (methylene chloride), $CHCl_3$ (chloroform), and CCl_4 (carbon tetrachloride) respectively. Other alkanes react similarly.

The *unsaturated* hydrocarbons react by *addition*. They are more reactive because of the tendency of the doubly and trebly bonded carbon atoms to become saturated. Chlorine *adds* to the unsaturated hydrocarbon.

$$CH_2=CH_2+Cl_2 \rightarrow \underset{\substack{\text{Dichloroethane}\\ \text{(ethylene dichloride)}}}{CH_2Cl—CH_2Cl}$$

Bromine reacts similarly.

$$CH\equiv CH+2Br_2 \rightarrow \underset{\substack{\text{Tetrabromoethane}\\ \text{(acetylene tetrabromide)}}}{CHBr_2-CHBr_2}$$

Aromatic hydrocarbons can undergo both substitution and addition reactions with chlorine depending upon the conditions.

$$C_6H_6 + Cl_2 \xrightarrow[\text{Catalyst}]{FeCl_3} \underset{\text{Chlorobenzene}}{C_6H_5Cl} + HCl$$

$$C_6H_6 + 3Cl_2 \xrightarrow{\text{Light}} \underset{\text{Benzene hexachloride}}{C_6H_6Cl_6}$$

Chlorobenzene is the chief raw material for making DDT, the well-known insecticide. Benzene hexachloride, BHC, is itself a widely used insecticide and is commonly called *gammexane*.

22.2—8 *How do hydrocarbons react with hydrogen ?*

The *saturated* hydrocarbons do *not* react with hydrogen at all. The unsaturated hydrocarbons react by addition, but only in the presence of metal catalysts like finely divided platinum, palladium or nickel. The reaction is called catalytic hydrogenation. The products formed are saturated hydrocarbons.

$$CH_2 = CH_2 + H_2 \xrightarrow{\text{catalyst}} CH_3-CH_3$$

$$CH \equiv CH + 2H_2 \xrightarrow{\text{catalyst}} CH_3-CH_3$$

Aromatic hydrocarbons give saturated hydrocarbons.

$$C_6H_6 + 3H_2 \xrightarrow{\text{Ni catalyst}} C_6H_{12}$$

Cyclohexane

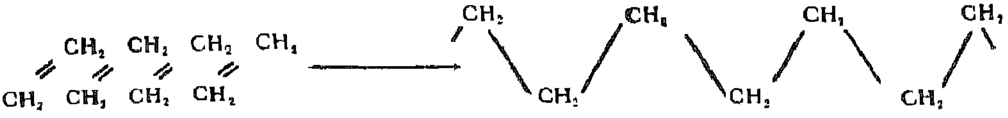
Addition reactions are more difficult to carry out with aromatic hydrocarbons than with unsaturated hydrocarbons. Generally, the aromatic hydrocarbons undergo *substitution reactions*.

22.2—9 *What is polymerization ?*

We have seen that unsaturated hydrocarbons undergo *addition* reactions with hydrogen, chlorine and bromine. But they can also undergo self-addition. Thus, many molecules of ethylene can combine with one another to form very long chains under suitable conditions. The product is the familiar *polythene* (poly thylene) used for making household articles like buckets, mugs, bags, wrappers, etc. Each molecule of polythene contains thousands of carbon and hydrogen atoms.

A reaction in which molecules of the same kind *add* to one another is called *polymerization.*

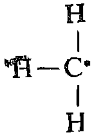
Many organic compounds containing double bonds undergo polymerization. Rubber is a naturally occuring polymeric hydrocarbon.



Part of a polythene chain

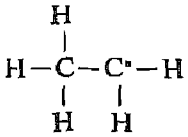
22.2—10 What are alkyl radicals ?

If one hydrogen atom is removed from an alkane, an unstable radical is formed. Such a radical is called an alkyl radical In a stable compound, all electrons are paired; in a radical there is one 'odd electron' Hence a radical is unstable and very reactive. Such radicals are formed only during chemical reactions. As soon as they are formed they undergo rapid reactions to give stable products.



$H_3C^{\bullet}$

Methyl radical



$H_3C{-}C^{\bullet}H_2$

Ethyl radical

22.3 What are reactive functions ?

Carbon-hydrogen bonds and carbon-carbon single bonds are strong and inert. But carbon-carbon double bonds and triple bonds are reactive as we have seen. Similarly C—Cl, C—OH, C=O, C≡N bonds provide reactive sites. Such reactive centres in organic molecules are called *reactive functions* or *functional groups*. Some common functional groups are :

$>C=C<$	alkene function or double bond	$-NH_2$	amino group
$-C\equiv C-$	alkyne function or triple bond	$>C=O$	carbonyl group
$-Cl, -Br$	halogen	$-C\begin{smallmatrix} {/\!\!/}O \\ \diagdown OH \end{smallmatrix}$	carboxyl group
$-OH$	hydroxyl group		

It is useful to regard an organic molecule as consisting of two parts - the *functional group* (reactive) and the *alkyl group* (inert). The functional group largely determines the chemical and physical properties of the compound. The size of the alkyl group affects and modifies mainly the physical properties. Many organic compounds contain more than one functional group.

22.4 Classification of organic compounds : Homologous series

Organic compounds are classified into a few series ; each series comprising compounds with the same functional group. They are arranged in the order of increasing size of the alkyl group within each series

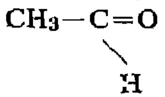
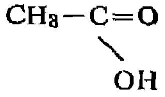
The chemical properties of the compounds in a series are the same The physical properties, like boiling points, change gradually as the alkyl group becomes bigger. One member differs from an adjoining member by one carbon and two hydrogen atoms. Such a series is called a *homologous series.*

Some Homologous Series

Alkanes	Alkenes	Alkyl chlorides	Alcohols
CH_4	–	CH_3Cl	CH_3-OH
CH_3-CH_3	$CH_2=CH_2$	CH_3-CH_2Cl	CH_3-CH_2OH
$CH_3-CH_2-CH_3$	$CH_3-CH=CH_2$	$CH_3-CH_2CH_2Cl$	$CH_3-CH_2-CH_2OH$

22.5 How are organic compounds named ?

The systematic names of organic compounds are based on those of the corresponding alkanes. Appropriate prefixes or suffixes denote the functional group present. Thus, compounds containing two carbon atoms are named as derivaties of ethane.

*Chloro*ethane	(Ethyl chloride)	CH_3-CH_2Cl
*Amino*ethane	(Ethyl amine)	$CH_3-CH_2NH_2$
Ethan*ol*	(Ethyl alcohol)	CH_3-CH_2OH
Ethan*al*	(Acetaldehyde)	 $CH_3-C(H)=O$
Ethan*oic* acid	(Acetic acid)	 $CH_3-C(OH)=O$

Eth*ene*	(Ethylene)	$CH_2=CH_2$
Eth*yne*	(Acetylene)	$CH\equiv CH$

The simple aromatic compounds are named as derivatives of benzene.

Chlorobenzene	C_6H_5Cl
Methylbenzene (toluene)	$C_6H_5CH_3$
Hydroxybenzene (phenol)	C_6H_5OH

Of course, many compounds are still being called by their old common names given within brackets above.

Petroleum

22.6 What is petroleum ?

We know that one of the most important fuels all over the world is petrol. It is one of the products obtained from a naturally occurring crude oil called *petroleum*. The oil is so named because it is found to occur under the earth's crust entrapped in rocks. (In Greek : Petra=rocks; oleum=oil). Besides petrol, a variety of other important products can be obtained from petroleum. Hence, there is a great importance of petroleum in relation to the economy of a country.

Petroleum resources in India: In India, petroleum is found in Gujarat, Assam and Maharashtra. We have now started producing oil from the high seas off Bombay.

Refining of petroleum: Petroleum is a complex liquid mixture of hydrocarbons It can be separated into a number of useful products by fractional distillation Each product is not a single compound, but a simpler mixture of compounds, which boil within a narrow temperature range. The process by which the various products are obtained from crude petroleum is termed *refining*. It is achieved by *fractional distillation*. In simple distillation, the vapours of the boiling liquid are directly condensed. In fractional distillation, the vapours are allowed to rise through a packed column in which the higher boiling liquids condense whereas the vapours of lower boiling liquids rise further. If the vapours are led from the top of the column and condensed, the distillate is rich in more volatile liquids (Fig. 22.1). Thus, a better separation is achieved. These fractions are further processed to prepare paraffin wax (used for making candles) and petroleum ether which is used as a solvent for extracting oils from

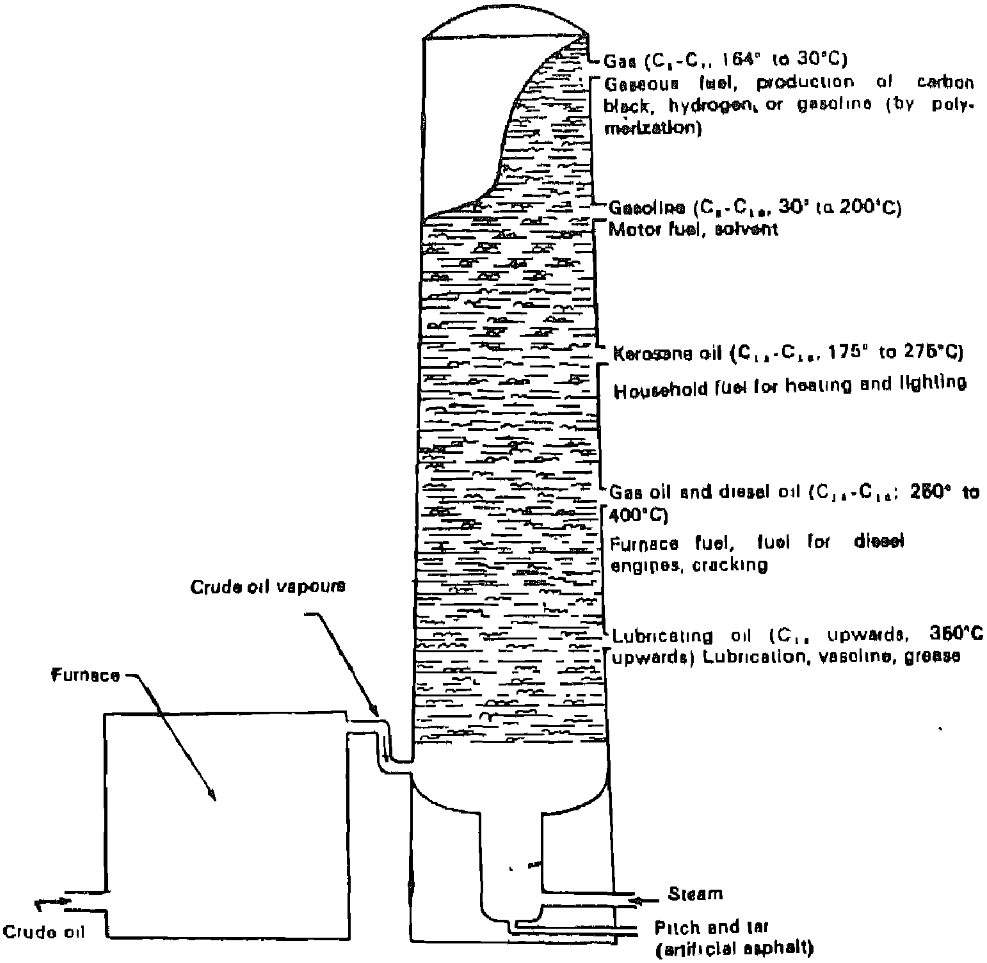

Gas (C_1-C_4, 164° to 30°C)
Gaseous fuel, production of carbon black, hydrogen, or gasoline (by polymerization)
Gasoline (C_5-C_{10}, 30° to 200°C)
Motor fuel, solvent
Kerosene oil (C_{11}-C_{16}, 175° to 275°C)
Household fuel for heating and lighting
Gas oil and diesel oil (C_{15}-C_{18}; 250° to 400°C)
Furnace fuel, fuel for diesel engines, cracking
Lubricating oil (C_{18} upwards, 350°C upwards) Lubrication, vasoline, grease
Crude oil vapours
Furnace
Steam
Crude oil
Pitch and tar (artificial asphalt)

Fig 22.1 Fractional distillation of petroleum

seeds and for dry cleaning. Tar on further distillation gives petroleum coke as residue which is used for making electrodes.

What is cracking ?

The hydrocarbons with high molecular masses that are present in gas oil and kerosene oil are not useful as fuels for the usual automobile engines because of their high boiling points. The process of heating by which these larger hydrocarbon molecules are broken down into smaller molecules, which are more volatile, is called *cracking*.

The chemical change during cracking is shown by the following example:

$$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3 \xrightarrow{\text{Heat}} CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3+CH_2=CH_2$$

which can be simply represented as

$$\underset{\text{Large alkane}}{C_{10}H_{22}} \xrightarrow{\text{heat}} \underset{\text{Smaller alkane}}{C_8H_{18}} + \underset{\text{An alkene}}{C_2H_4}$$

Thus, ethene, propene and isomeric butenes are the major by-products. However, these by-products are very useful. Because of their reactivity, they are easily converted into a variety of useful compounds. They are called *petrochemicals*. Petroleum is therefore not only a vast source of fuels, but also of useful chemicals, particularly those needed for making plastics.

EXERCISES

1. Why are the compounds of carbon studied as a separate branch of chemistry ?
2. What are the important properties of organic compounds which make them different from inorganic compounds? Give specific examples.
3. What is the general name given to all the compounds of carbon and hydrogen? Illustrate with examples.
4. Write names and formulae of some organic compounds containing single, double and triple bonds.
5. What is an aromatic hydrocarbon? Give one example.
6. How does benzene react with chlorine under different conditions?
7. What is the importance of combustion of hydrocarbons? Write an equation for the complete combustion of kerosene oil ($C_{14}H_{30}$)

8. Give two examples of reactions in which chlorine *adds* to a hydrocarbon, and two examples in which chlorine reacts with a hydrocarbon by *substitution*
9. How many alkyl radicals will be formed by the removal of a hydrogen atom from propane? Write their formulae.
10. What are the groups other than the hydrocarbon part that may be present in an organic compound?
11. Name different functional groups which are commonly found in organic compounds.
12. Write the functional groups present in the following compounds: CH_3COOH, CH_3OH, CH_3Cl, CH_3CHO
13. Write the structures of
    (i) propanoic acid
    (ii) propene
    (iii) propyne
    (iv) I-chloropropane
    (v) propanal
    (vi) aminobenzene
14. What is cracking ? What types of hydrocarbons are formed during cracking ?
15. How has petroleum derived its name ? What is its average composition ?

Chapter 23

Life Processes

23.1 Nutrition

All living organisms require a continuous supply of materials and energy to perform the different life processes. Several varieties of molecules are essential for the formation and maintenance of the body substances. Different groups of living organisms show different types of nutrition.

23 1—1 Autotrophic nutrition

Green plants synthesise all their food requirements from simple inorganic raw materials. A foodstuff is defined as a substance from which an organism derives energy and material for growth and maintenance. The green plants and a few types of bacteria which are completely self-supporting and are called *autotrophic organisms or autotrophs* This mode of nutrition in green plants is achieved mainly by the process of photosynthesis. Thus autotrophic organisms are able to grow and multiply in a purely inorganic medium. They do not depend on any outside source for their requirements of sugars, fats, amino acids and other complex molecules. The food manufactured or stored is translocated to different parts. It is digested inside the cell and is comparable to the intracellular digestion of animals.

23.1—2 Heterotrophic nutrition

All animals including man and non-green plants show heterotrophic mode of nutrition. *Heterotrophic organisms* or *heterotrophs* constitute a major category of living organisms. They obtain all their energy requirements mainly from organic substances like carbohydrates and fats. They derive their foodstuffs directly or indirectly from the plants. Since the green plants are the food makers, they are in fact the mainstay of the living world. When plant tissues are consumed by animals and men, the constituents of plant cells supply the building blocks of the body cells and the energy needed for the life processes of the animals and men.

The nutritional requirements of man are more complex than those of the other organisms. Compared with many other organisms the synthetic machinery of man is less versatile. Man depends on plants for the primary food supply either directly by taking plant products or indirectly by eating other animals that eat the plants. Man requires in his diet carbohydrates, eight of the twenty amino acids from which he can synthesise the other twelve and probably eight or more vitamins. The heterotrophic nutrition is of two types: *saprozoic or saprophytic and holozoic.*

In the saprophytic nutrition, for example, in non-green plants, the organisms secrete a starch-digesting enzyme to digest the food and then absorb the nutrients. In saprozoic organisms like the malarial parasite in man and *Monocystis* in earthworm the already digested food is absorbed by the process of diffusion. But nutrition in most of the free living animals is holozoic. In this type of nutrition, food may be a small organism, a plant or an animal. You are already familiar that this kind of nutrition takes place from protozoa to man. In all the holozoic organisms, whatever may be the food, it must be taken in (*ingestion*), it must be digested (*digestion*), simplified products must be absorbed (*absorption*) and the residual products must be removed (*egestion*). The details of each of these steps are given below.

INGESTION

Ingestion is the process by which food is taken by the organisms. We know that some organisms eat plants or plant products (*herbivorous*), some eat animals (*carnivorous*) and some eat both (*omnivorous*). In the simple organism like amoeba, food is taken in at any place on the cell surface and it moves directly into a special organelle called food vacuole. In multicellular organisms like *Hydra*, the food is ingested through the mouth on hypostome with the help of tentacles The earthworm has a muscular pharynx to swallow its food. Arthropods like cockroaches have special mouth parts adapted for catching and cutting the food. The vertebrates like frog, birds and mammals have well-developed devices to take in the food.

DIGESTION

Digestion involves various physical and chemical processes by which insoluble food is rendered suitable for absorption. In the unicellular organisms like amoeba (Fig. 23.1), the food in small food vacuoles is digested by the enzymes secreted by the cell cytoplasm. This is known as *intracellular* digestion. The higher organisms have special organs for the digestion of food. The food in these organisms passes through the alimentary canal. Here several digestive enzymes are secreted to break the complex food materials into simpler substances. This process takes place outside the cell and is called *extracellular* digestion.

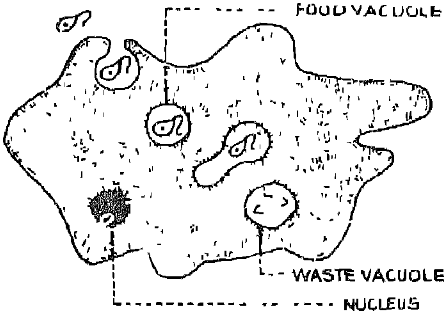


Fig. 23.1 Intracellular digestion in amoeba

Digestion of food in man

When we take food it is first mixed with saliva in the mouth and ground into a paste by the teeth. Saliva contains an enzyme called salivary amylase (*ptyalin*) which converts starch into sugar. Then the food is swallowed and is moved down into the stomach through the oesophagus. The presence of food in the stomach stimulates the tiny gastric glands to secrete enzymes, such as *pepsin*. Pepsin breaks down the proteins into simpler molecules known as peptides (small chains of amino acids). This process is aided by the secretion of dilute hydrochloric acid in the stomach. Sometimes, nervous tension and emotional upset result in the secretion of too much of acid causing hyperacidity. At this stage, the food takes turn into a soup. This soup enters the small intestine through the duodenum. Here the partly digested food is mixed with pancreatic juice secreted by the pancreas and bile secreted by the liver. The pancreatic juice contains enzymes like *trypsin*, *chymotrypsin*, *carboxypeptidase*, *amylase* and *lipase*. Trypsin and chymotrypsin act further upon some of the proteins and break them down into peptides and amino acids. Amylase turns the remaining starch into sugar and lipase acts upon the fats and converts them into soluble fatty acids and glycerol. The digestion which started in the mouth is completed in the small intestine. All these end products are suitable for absorption into the blood stream. The intestinal glands secrete enzymes like *aminopeptidases* and *disaccharidases* (*maltase*, *lactase*, and *sucrase*). The former completes the hydro-

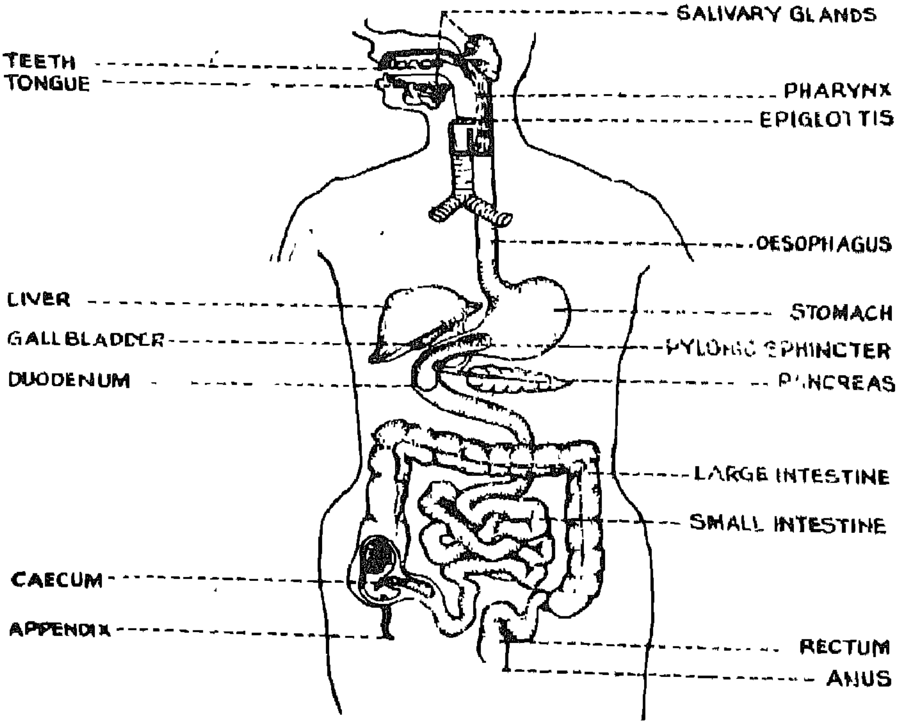


Fig. 23 2 The digestive organs and alimentary system in man

TABLE 23.1

Digestive enzymes : their sources and effects

Part of the digestive system	*Source of enzymes*	*Name of the enzymes*	*Substances acted upon*	*Products*
Mouth	Salivary glands	Salivary Amylase (Ptyalin)	Starch	Complex Sugars
Stomach	Gastric glands	Pepsin	Proteins	Peptides and amino acids
Pancreas	Pancreatic juice	Trypsin, Chymotrypsin and Carboxypeptidase,	Proteins	Peptides
		Amylase,	Starch	Maltose
		Lipase	Fats	Fatty acids and Glycerol
Small intestine	Intestinal glands	Aminopeptidases,	Peptides	Amino acids
		Disaccharidases (Maltase, Lactase, Sucrase)	Maltose Lactose Sucrose	Glucose and other Sugars

lysis of peptides into amino acids and the latter convert the disaccharides into monosaccharides. The digestive organs and alimentary system in man is shown in Fig. 23.2. Table 23.1 shows the different enzymes, their sources and their effects on the food. It is to be remembered that in all organisms, these enzymes are practically of the same nature.

ABSORPTION

In amoeba, the digested food is absorbed into the cytoplasm through the wall of the food vacuole.

The simplified products of digestion in higher organisms are absorbed in the small intestine through the intestinal wall which has numerous finger-like projections called villi.

EGESTION

Although many enzymes act upon the food material, some part of the food is left undigested. In unicellular organisms, these residual materials remain within the food vacuole and are finally discarded. In *Hydra*, such residual matters are discarded through the mouth In higher organisms, this residual undigested food is passed on to the large intestine, where the water in it is reabsorbed and the semiliquid material is converted into the semisolid faeces. The faeces is expelled through the anus periodically.

23.2 Photosynthesis

Photosynthesis is a unique process in the green plants which utilises solar energy and converts it into potential chemical energy. There are some bacteria beside the green plants which carry out photosynthesis. Virtually all life on this planet depend on the products of the reactions of photosynthesis. It is the only biological process that converts large quantities of radiant energy of sunlight into potential chemical energy. By means of this solar energy, the carbon dioxide from the atmosphere and hydrogen from water is incorporated into organic compounds at ordinary temperature. Photosynthesis serves as a bridge to utilise this free energy from the sun to the living organisms. The conversion of one substance carbon dioxide into the body constituent of another substance (sugar) is known as carbon assimilation or photosynthetic carbon assimilation

EXPERIMENT TO DEMONSTRATE EVOLUTION OF OXYGEN DURING PHOTOSYNTHESIS

1. Fix a rubber tubing to the tip of a 10 ml graduated pipette. Tightly close the rubber tubing with the help of a screw clamp. Fix the set-up to a burette stand (Fig. 23.3),

2. Collect a few *Hydrilla* twigs in a 500 ml beaker, after cutting them under water. The plants should be cut carefully without pressing
3. Fix the cut ends of the *Hydrilla* plants into the pointed end of the pipette.
4. Insert the pipette now in a beaker containing water. Fill the pipette completely with water Leave the set-up in sunlight. You will find the evolution of bubbles which displace the water in the pipette You can test the nature of the gas by introducing a burning splinter and show that it is oxygen.

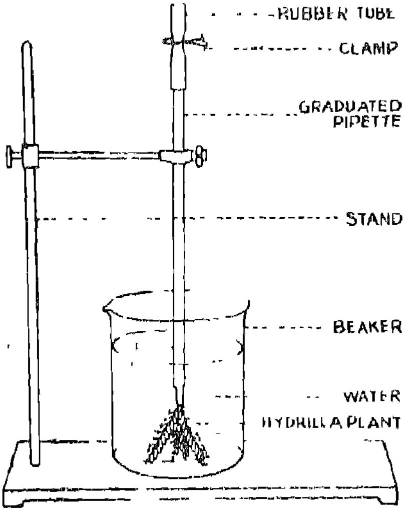


Fig. 23 3 The experimental set-up to demonstrate evolution of oxygen during photosynthesis

The radiant energy absorbed by the green leaves is used in transforming carbon dioxide and water into carbohydrates (sugar and starch). Oxygen is liberated during the process. Carbohydrates contain, in addition to carbon, the elements hydrogen and oxygen in the same ratio as in water.

$CO_2 + 2H_2O \longrightarrow (CH_2O) + H_2O + O_2$

The parenthesis around CH_2O means that no specific molecule is indicated; but merely the ratio of atoms in the carbohydrate is indicated. The energy stored in the foods in the form of chemical energy is continuously released in living cells during the process of respiration. In the carbohydrate the carbon atoms are derived from CO_2.

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

The summary reaction of photosynthesis does not indicate the step-by-step sequence of the multi-step process leading to the synthesis of carbohydrate molecule and release of oxygen The various reactions in the process are catalysed by many enzymes, each one specific for a particular reaction. The above equation does not indicate whether the oxygen evolved comes from water or from carbon dioxide. However, experiments using water containing heavy oxygen (i.e., oxygen with an atomic weight of 18) enabled one to follow the various chemical reactions and clearly demonstrated that oxygen liberated during photosynthesis comes entirely from water. This also indicates that the process of photosynthesis in higher plants involves the splitting of the water molecules and liberation of oxygen from them This event is called the photolysis of water. A more complete and revised equation of photosynthesis is indicated in the following overall equation.

$$6CO_2 + 12H_2O \xrightarrow[\text{chloroplast}]{\text{light}} C_6H_{12}O_6 + 6O_2 + 6H_2O + 114 \text{ kcal}$$

23.2—1 Photosynthetic raw materials

Carbon dioxide and water are the two basic raw materials for photosynthesis. Both carbon dioxide and water have low potential chemical energy while the product of photosynthesis is of high potential chemical energy. Carbon dioxide is obtained from the atmosphere. The atmosphere normally contains about 3 parts/10,000 parts by volume of carbon dioxide.

Carbon dioxide enters the leaf through tiny pores on the leaf surface called the stomata. Sometimes the carbon dioxide evolved during respiration in the plant is also utilised for photosynthesis. Water, the other raw material for photosynthesis, is absorbed by roots of the land plants from soil and is conducted through roots and stems into the leaves.

CHLOROPLASTS : THE SITE OF PHOTOSYNTHESIS

All the green parts of the plant carry out photosynthesis and the leaves of all plants are ideally developed for this purpose. The process of photosynthesis takes place entirely within the subcellular organelles called the chloroplasts. Chloroplasts of higher plants are lens-shaped or ellipsoidal and are found only in the green cells of plants. They are collectively known as plastids. By examining a leaf section you can observe that the green pigment is limited to certain plastids known as chloroplasts. The chloroplasts are most abundant in the elongated cells of the palisade tissue in the leaf. But they also occur in the cells of the spongy mesophyll. The chloroplasts contain the green colouring pigment called chlorophyll.

LIGHT AND CHLOROPHYLL

EXPERIMENT TO DEMONSTRATE THE NECESSITY OF CHLOROPHYLL FOR PHOTOSYNTHESIS

1. Cut a variegated leaf of *Coleus* or *Manihot* or *Croton* or any other variegated leaf from a plant that has been exposed for several hours to bright light.
2. Soak the leaf thoroughly in tap water, and place it on a dark background under a flat piece of glass. Lay a transparent paper on the glass, and trace the outline of the leaf and the boundary between the green and the non-green portions.
3. Kill the leaf by dipping it in a beaker of boiling water.
4. Dip the dead leaf in a beaker containing 70 per cent alcohol and allow it to stand until the colour is completely extracted. The colour can be rapidly extracted by placing the beaker on a hot plate.
5. Carefully take the leaf into a petridish. Immerse the leaf in a solution of iodine in potassium iodide.
6. Wash away the iodine with water. Compare the area stained blue-black with the area you have drawn as originally green. Notice that starch is formed only where chlorophyll is present (Fig. 23.4).

Visible white light as it comes to us from the sun is composed of light bands of different wavelengths. The band of colours in the visible spectrum consists of relatively long waves of red light through successively shorter waves ending into violet light. Human eye perceives the visible light of different wavelengths in the form of light of different colours. In photosynthesis the light in the region of blue and red wavelengths of white light is most strongly absorbed and utilised. Moist of the green light is reflected out and it is for this fact that chlorophyll is green to the eye. The unit of light absorbed in photosynthesis is referred to as a photon or quantum.

The chlorophylls are contained in the chloroplasts. The electron microscope has revealed that there are highly organised fine structures inside the chloroplasts. The photosynthetic pigment, i.e., the chlorophyll, absorbs light and mediates its conversion into chemical energy. The chlorophyll plays a purely catalytic role in photosynthesis. It is a complex organic molecule and contains

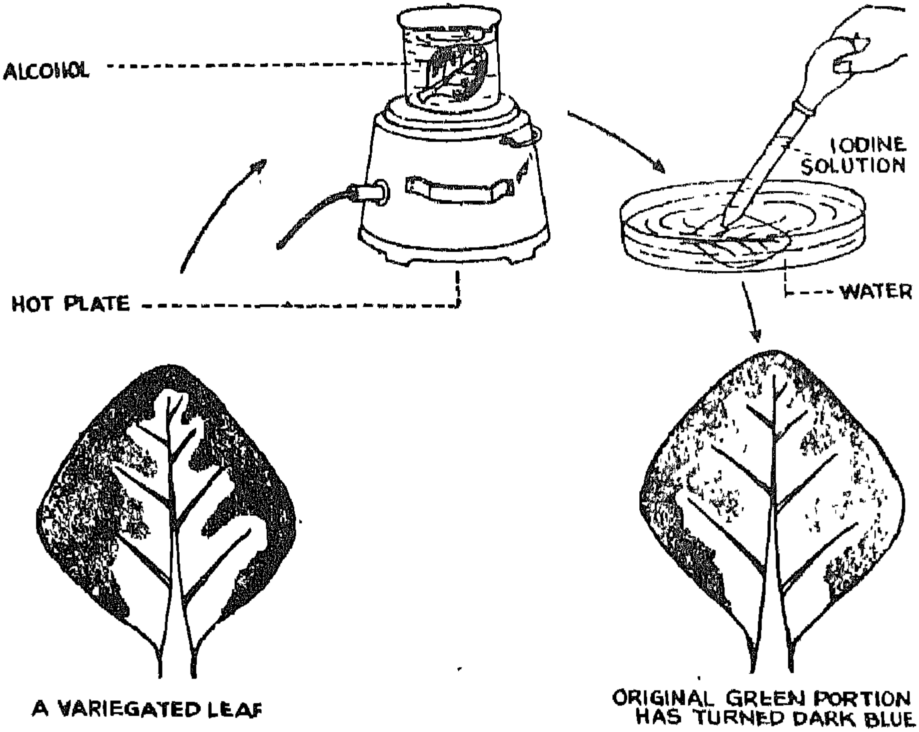


Fig. 23.4 The experimental set-up to demonstrate the necessity of chlorophyll for photosynthesis

magnesium at the centre. You have already learned that chlorophyll is a green pigment and it does not absorb green light. Other pigments like carotene and xanthophylls are also associated with the chlorophyll in the green plant cells. Their presence in green leaves is usually masked by the greater abundance of the chloroplast.

The process of photosynthesis is of vital importance in that it replenishes the oxygen in the atmosphere, which is consumed in animal and plant respiration. Man not only lives on the products of current photosynthesis but utilises the fossil remains of the products of photosynthesis in the geological past, like coal, peat, oil and natural gas.

23.3 Respiration

The various life processes taking place in plants and animals require available free energy. The energy released from the continuous breakdown of foodstuffs during respiration is used for the vital activities which are characteristics of life. Fig. 23.5 summarises the need for energy in living cells.

Respiration is a fundamental process of energy release and it occurs in all living cells. During respiration, energy-rich foodstuffs are oxidised to simpler substances like water and carbon dioxide coupled with the release of usable energy within all living cells. Respiration involves an exchange of gases, i.e., an uptake of oxygen and release of carbon dioxide. Respiration is not to be confused with breathing. During breathing organisms get oxygen from the environment into their bodies so that it can be carried through specialised organs of breathing. Release of energy occurs only via chemical reactions. Biologists usually term this energy releasing process as biological oxidation or cellular respiration. All the reactions of biological oxidation are catalysed by several specific enzymes. The principles of biological oxidation are essentially the same for all organisms from bacteria to man. This is one of the best examples of functional unity in spite of structural diversity in living organisms. Biological oxidation also serves to supply a pool of intermediate organic compounds that can be used for the synthesis of other essential compounds.

In chemical terminology a substance is oxidised when it loses electrons and reduced when it gains electrons. Now the term oxidation does not necessarily mean that it is limited to the combination of a substance with oxygen. If one substance becomes oxidised, there must be a simultaneous reduction, for the

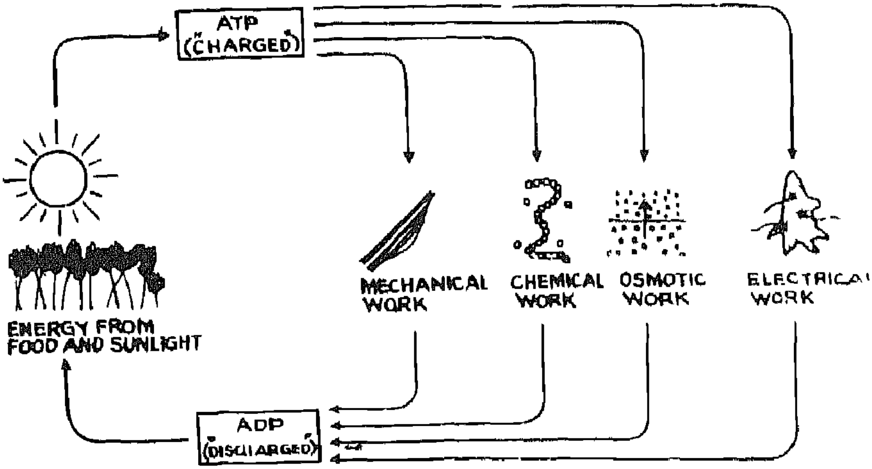


Fig. 23.5 ATP formation during photosynthesis and respiration and the use of this ATP in various cellular activities converting ATP into ADP

electrons lost by one substance are gained by another. The exchange of electrons is accompanied by the release or absorption of energy.

Cellular respiration is different from the burning of a candle or a match stick where oxygen of the air combines with the oil or wood and energy is released at once and is lost in the form of light and heat and the fuel is broken down into carbon dioxide and water. On the contrary, in cellular respiration, energy release is controlled and conserved in specific compounds capable of storing and releasing the energy when needed. Cellular respiration goes on at ordinary temperature. Even in biological oxidation some energy is lost as heat from the cell. A key substance, common to all organisms, which is the storehouse for this chemical energy is known as adenosine triphosphate or ATP. ATP serves as the universal intracellular carrier of chemical energy and it meets usually all the energy demands of the cell.

Glucose, a hexose sugar, is the usual organic substance which is utilised in biological oxidation. However, other substances like fat, organic acids and even protein are also consumed in respiration. The energy stored in glucose, as you have learned, is derived from sunlight.

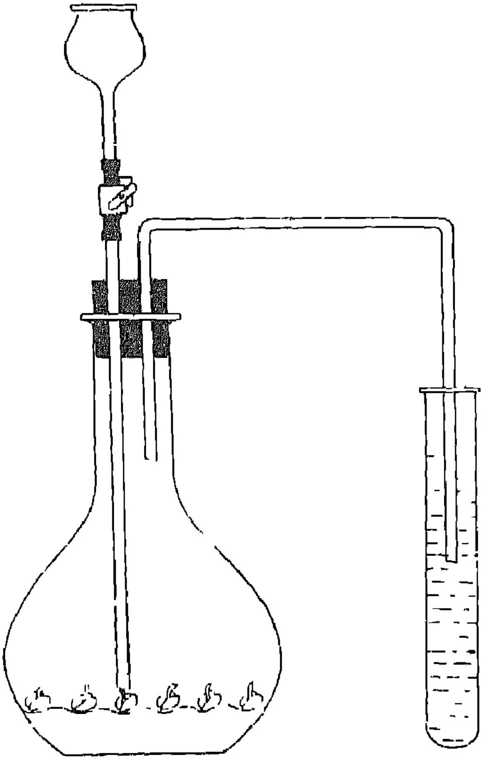


Fig. 23 6 The experimental set-up to demonstrate production of carbon dioxide during respiration

EXPERIMENT TO DEMONSTRATE PRODUCTION OF CARBON DIOXIDE IN RESPIRATION

1. Keep some germinating seeds in a flask and plug it with a two-holed rubber cork.
2. In one of the holes introduce a water reservoir with a provision for stop-cock.
3. Take a twice bent glass tube and connect the flask with a test tube contain-

g water through the second hole of the rubber cork as shown in Fig. 23.6.

Leave the set-up for an hour or two. Then replace the water of the test be at the open end with lime water. Leave the stop-cock of the reservoir such at water nearly fills the flask and the air of the flask is sent through the lime ater. The lime water is turned milky which shows that germinating seeds give f carbon dioxide during respiration.

.3—1 *The overall process of respiration*

As indicated earlier, respiration is a cellular process and it is also a mplex chemical process. It consists of numerous sequential chemical reactions nd all of them are enzymatically controlled. The overall process of respiration summarised in the following equation.

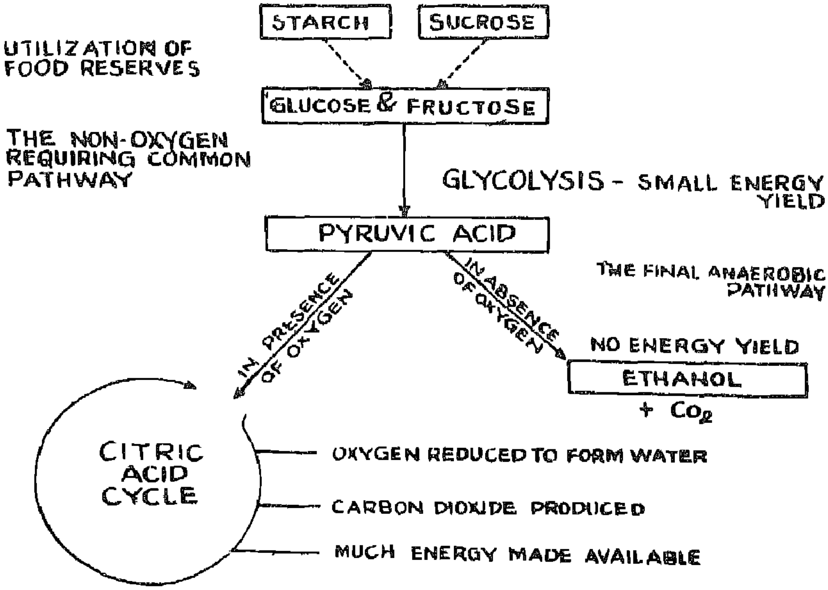

STARCH
SUCROSE
UTILIZATION OF FOOD RESERVES
GLUCOSE & FRUCTOSE
THE NON-OXYGEN REQUIRING COMMON PATHWAY
GLYCOLYSIS - SMALL ENERGY YIELD
PYRUVIC ACID
THE FINAL ANAEROBIC PATHWAY
IN PRESENCE OF OXYGEN
IN ABSENCE OF OXYGEN
NO ENERGY YIELD
ETHANOL
+ CO2
CITRIC ACID CYCLE
OXYGEN REDUCED TO FORM WATER
CARBON DIOXIDE PRODUCED
MUCH ENERGY MADE AVAILABLE

Fig 23.7 The sequence of events in respiration

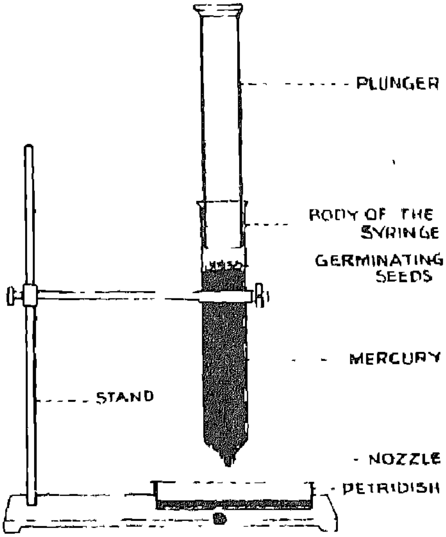


Fig. 23.8 The experimental set-up to demonstrate anaerobic respiration

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{mitochondria}]{} 6CO_2 + 6H_2O + 686\ \text{kcal}^*$$

→cytoplasm,
mitochondria

This equation represents the oxidation of hexose sugar, namely glucose, in the presence of oxygen from the air. The above equation merely indicates the two reacting substances, sugar and oxygen, and the two end products, carbon dioxide and water. But this does not indicate the complete reaction sequence or he pool of intermediate substances of the process. This breakdown of sugar nto carbon dioxide and water requires more oxygen than is contained in the lucose molecule. So oxygen has to be supplied from the atmosphere.

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*The complete oxidation of 180 g of glucose yields 686,000 calories of energy in the form of heat. Much of this energy is utilised in carrying out cellular activities. One gram mole of a substance is its molecular weight expressed in grams, e.g. one gram mole of glucose weighs 180 g

The units of energy are frequently expressed as kilo-calories (kcal) or as calories per mole of the substance.

The amount of the heat energy required to raise the temperature of one gram of water (at 15°C) by one degree Celsius is known as a calorie. (1 cal=4.18 Joules).

During the process of respiration, glucose first undergoes a series of hanges. The atmospheric oxygen does not enter into these initial reactions in hich some intermediate compounds are formed and small amounts of energy re released. This series of early reaction is known as glycolysis (Fig. 23.7). lycolytic reactions take place outside the mitochondria in the cytoplasm.

XPERIMENT TO DEMONSTRATE ANAEROBIC RESPIRATION

1. Remove the plunger from a syringe. Keep some germinating seeds of peas or Bengal gram in the syringe and introduce the plunger (Fig. 23.8).
2. Keep the nozzle of the syringe in mercury and carefully draw 3-4 ml of mercury into it.
3. Remove the syringe from mercury and by keeping the nozzle upwards expel the air from the syringe.
4. Keeping the thumb under the nozzle, bring the nozzle downward and keep a petridish underneath Loss of drops of mercury may be avoided by keeping a petridish below the syringe.

Leave the set-up for some time. The gas liberated from the seeds pushes p the plunger or pushes some mercury through the nozzle. The nature of the as liberated can be tested by introducing lime water or a burning splinter.

naerobic respiration: The further conversion of pyruvic acid depends upon he presence or absence of oxygen. When respiration is carried on without xygen pyruvic acid is incompletely reduced to ethyl alcohol (ethanol) and arbon dioxide in the final stage. These reactions are confined to the soluble portion of the cell cytoplasm.

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + 54 \text{ kcal}$$

The term glycolysis is usually applied to anaerobic breakdown of sugar. Thus, glycolysis involves a series of reactions starting from carbohydrate to actic acid by way of pyruvic acid in the absence of oxygen. The term anaerobic respiration' is limited to higher organisms and 'fermentation' refers o the breakdown of sugar by yeasts and bacteria. There are species among oth plants and animals which can tolerate complete absence of oxygen.

Yeast produces alcohol during fermentation, but if oxygen is available it is utilised to carry on aerobic respiration. Fermentation by yeast is also characterised by the production of a variety of end products. Yeast is extensively used for fermenting fruit juices in the production of alcoholic beverages

In the human body, during muscular exercise energy demand is in excess than that is supplied by respiration. There is insufficient supply of oxygen from lungs through blood vessels and through cell membrane into cells. Muscle cells carry on anaerobic respiration temporarily. Under these conditions lactic acid is accumulated, which is slowly removed in the blood stream or reoxidised during the resting period. In man and most animals the cells can carry on anaerobic respiration for some time but ultimately they must have oxygen to continue the more efficient aerobic process.

Aerobic respiration: In the presence of oxygen pyruvic acid becomes further oxidised by dehydrogenation to carbon dioxide and water through the reactions of oxidative cycle; water is formed due to the combination of oxygen with the hydrogen The cells usually obtain their energy requirements in bulk through aerobic respiration. These reactions occur within small structures that are present in the cytoplasm known as mitochondria. Mitochondria are barely recognisable as oblong or rod-like structures when viewed under a light microscope. These structures are generally considered as the power plants of the cell. A series of cyclic reactions take place in the mitochondria and is known as Krebs cycle (or TCA cycle or citric acid cycle). The greatest energy turnover occurs during the terminal stages of oxidation of pyruvic acid to carbon dioxide and water. Thus the overall process involving the complete oxidation of glucose to carbon dioxide and water is called aerobic respiration (glycolysis plus Krebs cycle). From the foregoing account it is clear that glycolysis, fermentation and respiration share a similar sequence of reactions up to the formation of pyruvic acid.

The importance of cellular respiration lies in the production of ATP from glucose. The controlled step-by-step oxidation of glucose in cellular respiration permits a bulk of energy conserved as chemical energy in the form of ATP

One of the fundamental principles in fruit and vegetable storage is to reduce the rate of cellular respiration, which tends to prolong the storage life, i.e , the transition from mature green to ripe stage Generally lower temperatures reduce the respiration while higher temperatures hasten ripening.

4 Internal transport

The complex structural organisation of multicellular organisms requires a hanism to transport materials throughout the body. In simple multicellular anisms like hydra and in unicellular organisms like amoeba, paramoecium, *amydomonas* and other algae, this is achieved by diffusion. The transport in re complex animals is carried out through the circulatory system. In higher nts, the transport within the body is carried out through the conducting ues like xylem and phloem and through the intercellular spaces.

4—1 *Transport in unicellular organisms*

You are already familiar with the unicellular organisms like amoeba, amoecium and algae The gases, minerals and organic substances which are solved in water get into the cells of these organisms mainly by an active cess which requires energy and also partly by diffusion. In the same way, the ste materials from these organisms are removed from their body.

.4—2 *Internal transport system in man*

In all vertebrates a liquid tissue is always kept circulating throughout the dy. This liquid tissue is called blood. It is circulated through narrow, elastic, sed tubes—the blood vessels. Blood is kept continuously moving in the ood vessels by the pumping action of the heart.

The schematic structure of the circulatory system in man is shown in g. 23.9. The heart, in fact, has two water-tight chambers, the receiving amber called auricle (atrium) and the distributing chamber called ventricle. e left half of the auricle receives purified blood from the lungs and empties to the left ventricle. The left ventricle distributes blood to various organs and sues through the blood vessels. These blood vessels which carry blood from e ventricle to the tissue are called arteries. These have thick elastic walls hich can contract. On reaching the concerned organ each artery divides into terioles of small dimensions. These in turn divide inside the tissue into pillaries of finer dimensions. It is here that the blood gives off its food and xygen and collects carbon dioxide and waste materials. This is possible beause the walls of the capillaries are extremely thin. The blood that has become npure through the collection of waste materials is now cleared from the tissues y a set of blood vessels called veins. Several veins from different organs join

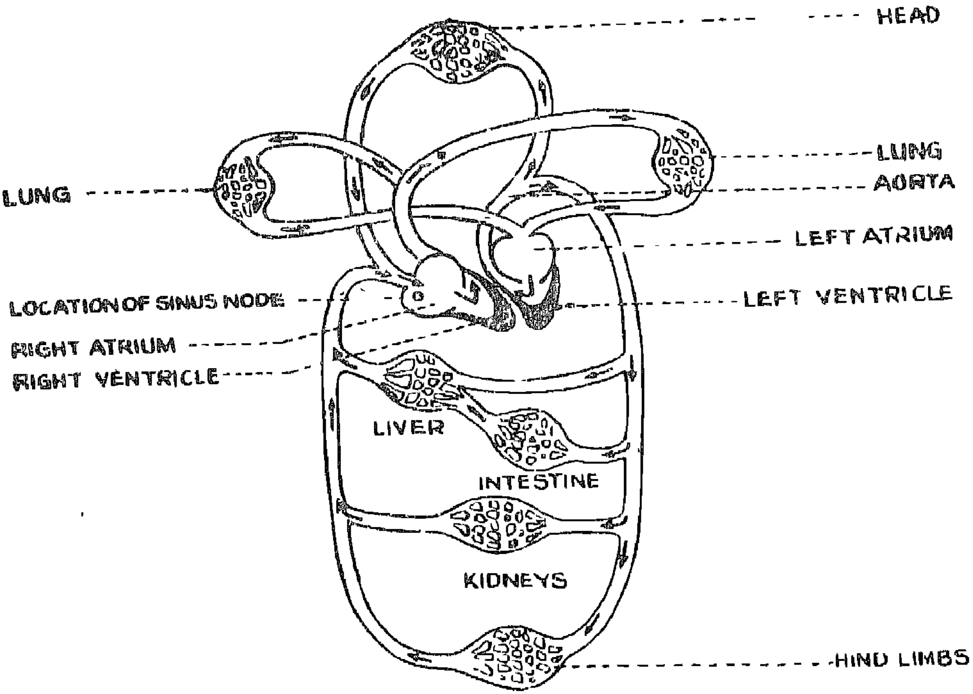

Fig. 23.9 A schematic representation of the circulatory system in man

to form venous trunks or venae cavae. The two venae cavae empty the deoxygenated blood into the right auricle. From here, the blood is passed on to the right ventricle which pumps it to the lungs for oxygenation The oxygenated blood returns to the left auricle. Thus the circuit is completed.

Thus, nowhere in the body the blood actually comes into direct contact with the tissues It is always inside the blood vessels Therefore, this type of circulation is called 'closed circulation'. When the blood flows from the arterial end or the capillaries to its venous end, due to pressure differences, fluid filters out of the thinwalled capillaries at the arterial end. This fluid is called the tissue fluid. It carries with it salts, sugars, amino acids and gases dissolved in it. The excess tissue fluid either gets back into the capillaries at their venous ends or s back through another system of transport vessels, the lymphatic system. e excess tissue fluid collected by these lymph vessels is finally poured back o the blood as lymph into the large venous trunks. There it mixes with blood d loses its identity.

The heart goes on beating from long before the time of birth to death. goes on contracting and relaxing alternately. It does so to pump blood rough blood vessels and to keep it moving. The contraction is called systole d the relaxation diastole The heart can beat on its own accord without any rve supply. But the heart is supplied with nerves. These nerves serve to control e rate of heart beat. The beat can either be hastened or slowed down by ese nerves. The normal rate of heart beat in man at rest is 65—75 per inute.

This fluid tissue, the blood, consists of various cells and cell-products oating in a watery substance known as the plasma In a healthy person about .6 litre of blood is present. The plasma is composed principally of water with large number of proteins, called plasma proteins. These plasma proteins help n retaining water, in clotting of blood at the site of injury, and in combating isease producing organisms. The plasma also contains sugars, salts, amino cids, oxygen and other substances useful to cells. The waste products of cells, uch as urea, carbon dioxide and others are also present in plasma. The red lood cells (RBC) are the most numerous in blood. Each cubic millimetre of lood contains about 5 million RBCs. They are produced in bone marrow By he time they reach the blood stream they lose their nuclei. Each is a tiny bag f haemoglobin which can carry oxygen or carbon dioxide. The white blood ells (WBC) are less numerous. About 5,000 to 7,000 are seen in one cubic millimetre of blood. They are formed in bone marrow, lymph nodes and spleen. The white blood cells are of different types. They protect the body against infection and disease. In addition to RBCs and WBCs, blood also contains small cells called blood platelets These blood platelets help in clotting of blood at the site of injury.

23.4—3 Transport of materials in plants—translocation

Plants utilise simple inorganic substances like carbon dioxide, oxygen, water and mineral salts for all their synthetic activities. You have already learnt that carbon dioxide and oxygen are taken from the atmosphere by the leaves.

Water and dissolved mineral salts are absorbed by the root system and are conducted to the leaf and stem tip where they are utilised. You have studied that water is utilised in the leaves where it participates in photosynthesis.

Sugars are manufactured in the leaf by the process of photosynthesis and are translocated from the leaves into the stem. Along the stem they are redistributed to sustain the growing points of root and shoot, to storage organs and during reproduction to the developing flower.

All this movement of substances from one region of synthesis or plentiful availability (source) to the region of utilisation (sink) is called translocation This is essential for carrying out the various vital activities of the land plant. In a land plant, xylem and phloem tissues are concerned with the translocation of these substances.

PATH OF TRANSPORT

Translocation occurs in the tissues of xylem and phloem. The xylem consists of thick walled tubes of dead cells. Water is conducted through the xylem from the root to the leaves, where it is partly utilised and the bulk of it is evaporated from the leaf surfaces. Minerals dissolved in water are absorbed from the soil and are moved upwards to the leaves mainly by way of xylem. So xylem forms the 'pipeline' for conducting water. On the other hand, the synthesised foods are conducted from the leaves to the roots and to the shoot tips through phloem tissue which consists of living cells. These cells are joined end to end; their end walls are sieve-like and are perforated. These are called sieve tubes (Fig. 23.10). Sucrose is the main form in which carbohydrate is transported in the phloem. Both xylem vessels and sieve tubes form continuous ducts which extend almost from the root tip to the stem tip. The thin walled sieve tubes are supported by fibres in certain plants. In jute and hemp these fibres are extensively developed and the fibres are of economic importance.

DEMONSTRATION OF THE TRANSLOCATION OF FOOD MATERIALS

The movement of food substances in plants can be demonstrated experimentally by removing the bark, known as girdling. Girdling blocks the movement of food substances down the trunk. Sugar moves through the plant both upwards and downwards. In pumpkin (*Cucurbita moschata*) food substances move from the leaves to other parts through the phloem at the rate of

160 cm in an hour.

EMONSTRATION OF TRANSPORT OF WATER

The transport of water in the xylem can be easily examined by placing a ut shoot of a balsam (*Impatiens* species) plant, in dilute eosin or safranin dye. After a few hours, sections from the terminal region clearly indicate the presence f the dye in the xylem region. This can be demonstrated by another simple xperiment. Cut two leafy shoots from a woody plant and carefully apply wax o cover xylem in one twig and phloem in the other as shown in Fig. 23.11. Leave the twigs in water. When the xylem is blocked, it prevents the conduction of water and the plant wilts On the other hand when the phloem is blocked the plant remains unaffected.

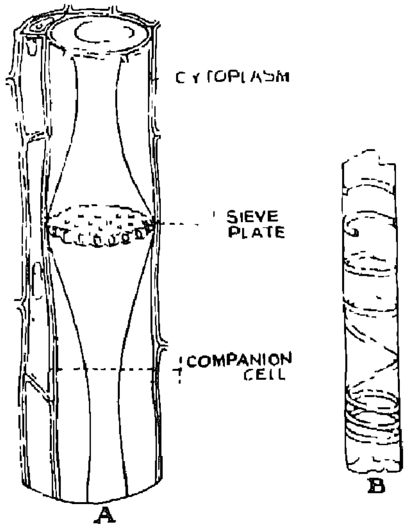

Fig 23.10 A. Sieve plate connecting two sieve tubes
B. Xylem vessel of a flowering plant showing thickened wall

There are several theories to explain the uptake of water. Sir Jagadish Chandra Bose suggested that water moves up by a pulsatory movement of the cells. Of course, his findings have not been confirmed by other scientists.

In agricultural practices, making use of the principle of translocation certain mineral deficiencies are made good by applying the nutrient solution through the leaves. Many of the pesticides, herbicides and growth regulators used extensively in agriculture depend on their effects on the principle of translocation.

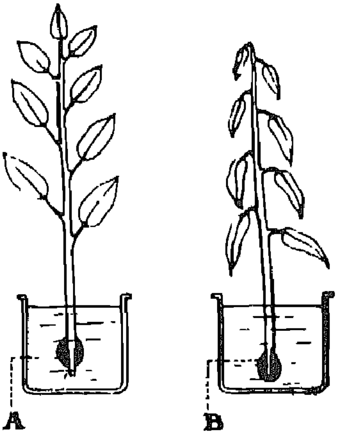

Fig. 23 11. Experiment to demonstrate the transport of water by blocking phloem (A) and xylem (B)

23 5 Excretion

You have already studied that plant and animal cells are engaged in various synthetic and oxidative reactions for the normal life processes of the organisms In the course of these reactions, numerous waste products are formed which are unwanted and often toxic (Fig. 23.12). The natural mechanism does not allow these substances to accumulate and the organisms possess one mechanism or the other in order to eliminate them from the system. The process by which such waste products are removed from the body of an organism is called excretion.

You have learnt that carbon dioxide and water are the byproducts of respiration in plants as well as in animals. These are excreted by a simple process of diffusion from the surface of the body in lower plants and animals, through the stomata in the leaves, through the gills in fish and lungs in man.

23.5—1 Excretion in man

Apart from the carbon dioxide which is excreted through the lungs, almost all other waste products in the body fluid are removed by special organs known as kidneys (Fig. 23.13). You know that in human beings there are two kidneys attached to the dorsal side of the body wall, one on either side of the vertebral column. Each kidney is connected with the urinary bladder by a duct called ureter. It opens to the exterior through urethra. Each kidney is made up of about a million of long, coiled fine tubes called nephrons. A nephron opens into a duct that collects urine, while the other end is in the form of a hollow cup known as Bowman's capsule. It surrounds a capillary tuft known as glomerulus. The glomerulus originates from the renal artery. The removal of urea and other waste products in the blood takes place between the glomerulus and Bowman's capsule. The blood leaving the glomerulus, now free of its waste products, passes out of the kidney through the renal vein.

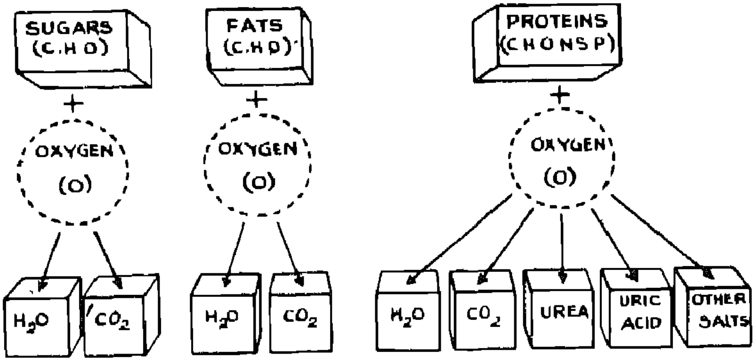

Fig. 23.12 The waste products are formed when sugars, fats and proteins are oxidised

The incoming blood in the artery and its capillaries has a high concentration of urea. The tubule has a low concentration of urea. The nephron filters the blood. How does the filtering take place? The blood in the glomerulus is under pressure which causes water and other soluble molecules present in the blood to filter through the capillary walls. The fluild produced is called the nephric filtrate. The nephric filtrate is simply blood plasma minus almost all the blood proteins. The nephric filtrate collects within Bowman's capsule. From there it passes into the proximal part of the tubule (Fig. 23.14). It is in this part that the reabsorption of glucose, amino acids, vitamins, hormones and a large quantity of mineral salts take place. The reabsorption takes place by a process of active transport. ATP generated in the mitochondria and certain specific enzymes are involved in the process of reabsorption.

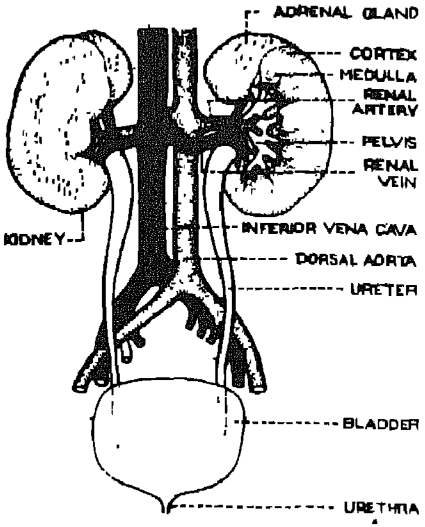

Fig 23.13 The kidneys and the associated structures in man. The left kidney has been partially sectioned to show the internal structure.

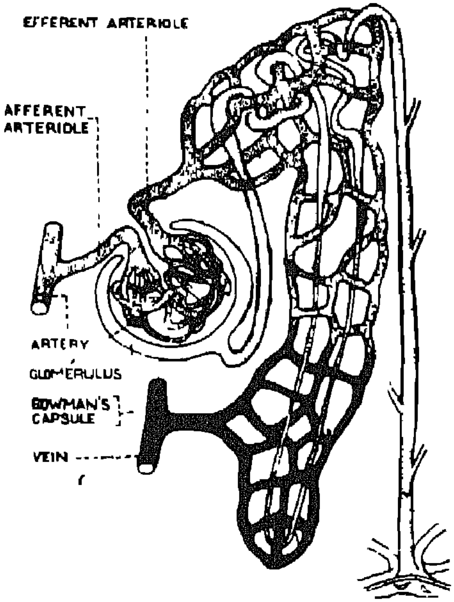

Fig. 23. 14 Detail structures of a nephron with its capillary network.

The materials reabsorbed by the proximal tubules are returned to the blood stream which surrounds the tubules. Along with the various components of the nephric filtrate that are reabsorbed and returned to blood, a large amount of water flows. This water is reabsorbed in the proximal tubule by the process of osmosis. The transfer of solutes from the nephric filtrate to the blood results in an increase in the proportion of water in the nephric filtrate. The water then passes into the blood by osmosis and restores the osmotic equilibrium.

The quantity of nephric filtrate produced in the millions of nephrons is considerable. Nearly 80 per cent of water in the nephric filtrate is reabsorbed by the proximal tubule.

It is estimated that considerable amounts of sodium bicarbonate, sodium chloride, glucose and smaller amounts of other useful substances, along with water, are all reabsorbed in the tubule itself. Now you can well appreciate that life cannot be sustained for long if this process of reabsorption fails and the materials simply pass out of the body. Thus an important function of the kidneys is balancing the amount of water in the blood with the amount of water in the cells. If this is not done osmosis may cause excessive amounts of water either to enter or to leave the cells causing disruption of the normal functioning of the body leading to death. It is estimated that nearly 180 litres of fluid are filtered daily by the kidneys. But the urine formed is only 0.5 to 1 litre. The urine is collected by the collecting tubules and drained into the bladder through the ureters. The urine collected in the bladder contains the final waste products such as urea and some inorganic salts.

OTHER ORGANS OF EXCRETION IN MAN

Along with the kidneys, four other major organs are also involoved in excretion. These are skin, lungs, intestine and liver.

Skin : The skin acts as an organ of excretion with the help of the sweat glands present in it. These glands remove water, urea and some salts from blood and excrete them on the surface of the skin The excretion of water by sweat glands aids in regulating the body temperature whenever there is vigorous muscular exercise; or if the external temperature is high, the temperature of the blood tends to rise and consequently sweat is produced. Evaporation of sweat cools the skin and aids in maintaining a constant internal body temperature.

Lungs · The lungs are the chief organs of respiration. They absorb oxygen and eliminate carbon dioxide The loss of water vapour during breathing is an unavoidable consequence. The alveoli of lungs must remain moist if they are to remain in an active state But the air that you breathe in is dry and this causes steady loss of moisture The rate of respiration is regulated by the nerves. Human beings breathe normally about 15 times per minute.

Intestine : The intestine plays a minor role in excretion. It has a lining of epithelial cells. These cells excrete certain salts, for example, those of calcium and iron. These salts are eliminated along with the faeces. However, the undigested food material in the intestine does not enter into the blood or cells. Therefore, it is eliminated from the body as faeces This process is better called egestion rather than excretion.

Liver: The liver is an excretory organ. However, it plays only a minor role in excreting waste products directly from the body and hence it may also be considered as an accessory excretory organ. Urea, the chief nitrogenous waste material in the human body, is formed in the liver The break-down of amino acids, which takes place in it, results in the accumulation of nitrogenous wastes. These nitrogenous wastes break down further into ammonia. Ammonia is a very toxic substance and its accumulation is therefore dangerous and even fatal. However, the liver converts the ammonia along with carbon dioxide into urea with the help of specific enzymes. Urea is removed by the kidneys eventually.

The haemoglobin of the dead red blood cells is broken down in the liver. In this process, the liver manufactures bile pigments. Through the bile ducts, the bile pigments pass into the intestine and are thrown out along with the faeces. In fact, the bile pigments are the true metabolic wastes in faeces.

23 5—2 Excretion in plants

Plants absorb the required amounts of nutrients and water from soil and atmosphere. Therefore, compared to an animal, the elimination of wastes is much less in plants. The rate of catabolism in plants is usually much lower than in animals Metabolism in the green plants is versatile in the sense that they are capable of utilising some of the waste products of catabolism in the anabolic process. Leaves, bark, roots and seeds usually are concerned in the process of eliminating or storing excess or waste materials

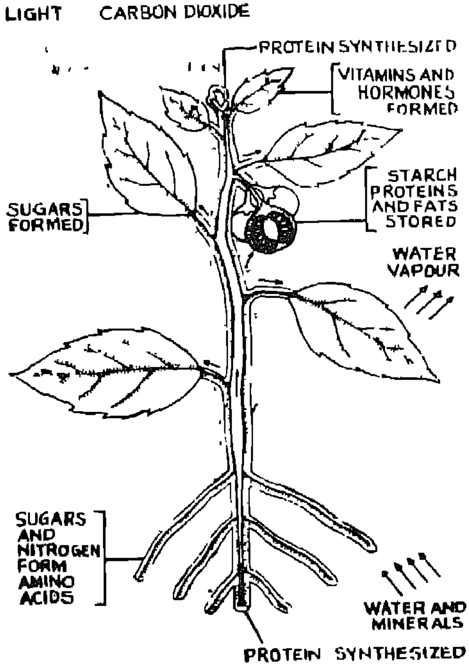

Fig 23.15 Synthetic activities of a plant

Water and carbon dioxide which are the end products of respiration are mostly utilised in photosynthesis Likewise, the end product of photosynthesis, namely oxygen, is utilised in respiration Ammonia formed by the break-down of proteins and other nitrogenous compounds is utilised by the plants in the synthesis of other proteins (Fig. 23.15). The following are some of the substances which are exuded by the plants: sugars, proteins, amino acids and other organic acids. Some of the waste materials of metabolism include a variety of compounds belonging to the category of terpenoids, phenols and alkaloids. Various alkaloids and tannin belong to these categories of waste products and are of economic importances

Plants growing along the sea coast possess structures and mechanisms for the excretion of salt from the leaf surface. The salt is finally removed from the leaf by the action of wind and water The aquatic plants excrete the waste substances into the surrounding water.

The metabolic waste products are sometimes stored in the plant. They are stored in some plants in the form of crystals in the cells or confined to the vacuoles or stored in the bark. In the tree species the heart wood serves as a reservoir of waste products. Leaf shedding or fall is a common phenomenon in plants and several metabolic and mineral waste substances are disposed off in this manner. Shedding of the bark by tree is a similar phenomenon.

You have learnt in the chapter on circulation that water and dissolved nutrient elements are absorbed by the roots of the plants. It is of interest to note that healthy roots exude into the soil a variety of organic substances including carbohydrates, amino acids and organic acids. These are known as root exudates and form the substrates for microbial activity in the soil. They also influence the qualitative and quantitative changes in the micro-organisms around the root zone in the soil.

23.6 Movement and locomotion

All living organisms show some kind of movement. Animals have the ability to move freely. Movement can be seen clearly in animals since they possess definite organs of locomotion. Plants and animals are generally differentiated on the basis of their ability to move or the absence of it. Though movement is quite common in plants it is not always apparent.

Most animals move from place to place in search of food and to escape from their enemies. Animals showing such locomotion are described as motile. Locomotion in animals is accomplished in a number of ways.

23.6—1 Locomotion in protozoa

Let us consider the locomotion in the protozoans like amoeba and paramoecium. Amoeba moves about putting forth false feet called pseudopodia which are transitory in nature (Fig. 23.16). Amoeba covers a few centimetres per hour. Paramoecium has hundreds of small cilia arising from its body. In the unicellular forms, like euglena, a single flagellum is present.

Flagella and cilia represent the projections of cell body and are primarily locomotor structures (Fig. 23 17 & 23.18). The flagella show whiplike motion and cilia oar-like motion. Thus we find that in protozoa flagella, pseudopodia or cilia are concerned with the movement of the organisms

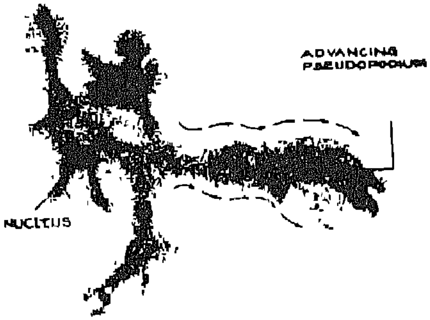

Fig. 23.16 Movement of amoeba through pseudopodia

23.6—2 *Locomotion in multicellular animals*

HYDRA

Hydra is a simple multicellular animal. Usually it remains attached to water plants by its closed end called the foot. It serves as a locomotory organ also. At its free end is situated the mouth, which is surrounded by tentacles. The tentacles are tubular slender structures Some of the cells of the outer layer of the tentacles have the ability to contract. It moves about by alternately elongating and shortening. Locomotion in hydra is brought about by floating, looping or by somersaulting (Fig 23 19) In looping movements the body contracts on one side so that the tentacles grip the support. The foot of the hydra relaxes its hold from the substratum and is drawn towards the tentacles. It attaches to the substratum near the tentacles. The tentacles are then released and the body becomes straight. Hydra also moves by a series of somersaults. It may swim through the water by its tentacles.

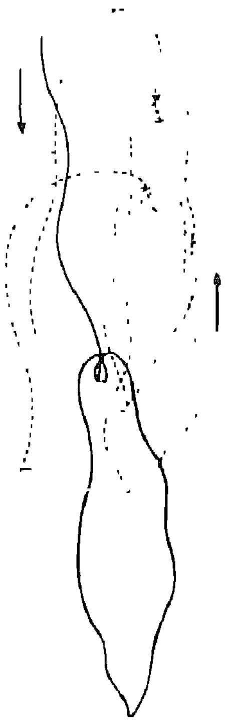

Fig 23.17 Locomotion in euglena

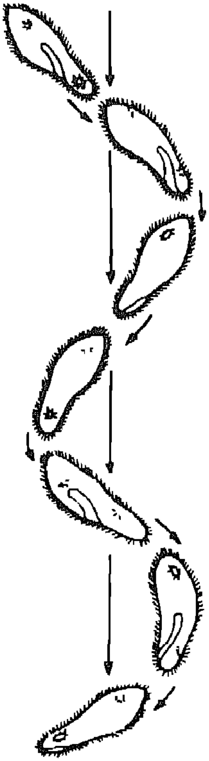

Fig 23.18 Locomotion in paramoecium

EARTHWORM

The earthworm moves slowly using its muscles and bristles in order to get food. During locomotion the earthworm grips firmly the hind part of the body on the soil with the help of the bristles on its under surface. Then it extends its front end. Later the front part of the body is fixed in the soil and the rear part is raised and contracted. The earthworm moves from place to place by repeating this process. In earthworm and other higher animals the property of contraction is highly developed in certain cells only. These cells are called muscle cells and they are specialised for bringing about movement through contraction. These muscle cells together with certain amount of connective tissue constitute the muscle

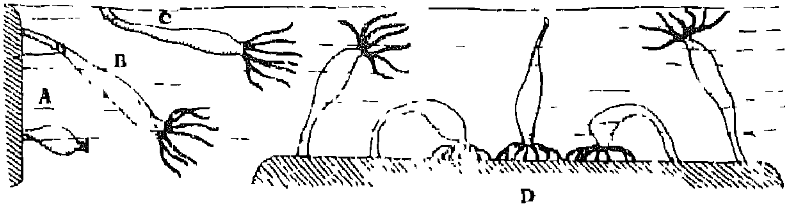

Fig. 23 19 Movement and locomotion in hydra ; A. Contracted; B. Expanded; C. Floating, and D Somersaulting.

INSECTS

Insects constitute the largest group of animals They have a terrestrial-aerial habit. They usually possess two pairs of wings to carry them over long distances in their flight They have three pairs of walking appendages in the adult stage. Wings of insects beat rapidly. They represent the simple modifications of the cuticle. Insects such as locusts migrate in large numbers. Swarms of these locusts move from one part of the world to another. They are a serious menace to many of the crop plants.

FISH

Fishes are adapted to life in water They have a streamlined body which facilitates easy movement in water. A fish causes several jerks in water by bending its body and moves forward (Fig. 23.20). A fish balances itself in water and controls its movement by the fins on its body. The pectoral fins on the body of the fish work like oars of a boat while the tail fin can be compared to the rudder of a boat. The tail fin is used to change the direction of movement.

FROG

Frogs are the most common amphibians showing two phases of lives.

The young tadpole lives in water and the adult frog moves on the land and in water. The movement of the tadpoles in their early stages is similar to that of fishes. In frogs the hind limbs are long and strong. Frogs swim with the help of hind limbs. The webbed feet of frogs push the water backward and this causes the forward movement of.the frogs. Their movement on land is caused by a series of leaps.

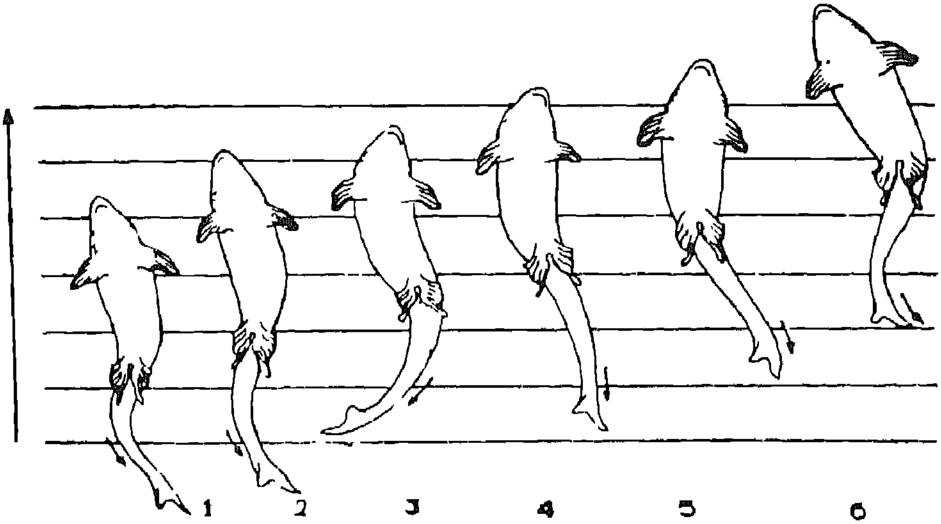

Fig. 23.20 Successive strokes for forward movement of a fish

REPTILES

The bodies of the reptiles are covered with scales. The digits are provided with claws. The reptiles show a crawling motion. Snakes and the lizards belong to this group. They are slow moving. The snakes are limbless reptiles.

BIRDS

Birds are feathered bipeds. Their forelimbs are converted into wings. They have a pair of walking appendages. Birds are adapted for flying long distances. The structural features of a bird are extremely suited for its flight in the air. Their wings are modified forelimbs with flesh and bones covered with feathers. They have normally short tails bearing feathers. The tails assist in steering the birds during flight. The movement of birds depends upon the strong muscles of the breast. Birds fly over long distances primarily in search of favourable environments where food and breeding facilities are available. Thus birds move periodically from one region to another and come back to their original region. This phenomenon is known as bird migration. The jungle fowl migrates all the way from the Himalayas to the Nilgiris covering a distance of about 2,200 km each way to escape the hardship of severe Himalayan winter. Several other birds are known to migrate from various foreign countries to India to escape severe winters. The bird migration is mostly north to south and back.

MAMMALS

Some of the largest animals living today belong to this category. For example, the elephants on the land and the whales in the sea are mammals. Many mammals generally use their hind-limbs as well as the fore-limbs for movement Quick moving animals walk or run on their toes and keep their wrist and ankle raised high above the ground. Some of the mammals like horses and cheetah can attain very high speed on land. The cheetah can run at the speed of 100-110 km/hr.

Bats are winged mammals and can fly. The wings of bats move with the help of powerful breast muscles. They move about in the night and have very poor eye sight. The bats have a remarkable echo apparatus, a radar system, to choose their directions of flights and locate and catch the insects. The bats have sensitive ears which can pick up the supersonic sound waves Monkeys use both hind-limbs and fore-limbs in their movement. Man having assumed the upright posture is entirely dependent upon the hind-limbs for his movement. Whales in water swim with the help of paddles which are modified fore-limbs.

The bulk of the mucles in the human body or, as a matter of fact in any vertebrate, are concerned with the locomotory movement besides providing support to the body. They are all striped voluntary muscles (Fig. 23.21). The other types of muscles in the human body are the smooth involuntary muscles and the cardiac muscles are concerned with other movements, but not with locomotion.

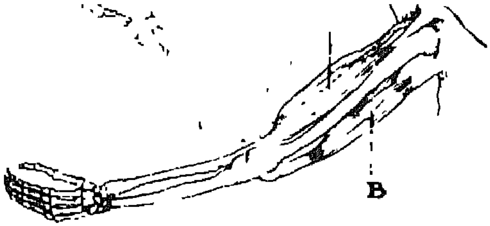

Fig 23 21 Voluntary muscles (A and B) in the arm of man

In all the vertebrates and many invertebrates with a skeleton, the locomotory movements are not brought about directly by the muscles alone. The contraction and relaxation of these muscles move the bones or the skeletal parts and this skeletal motion produces the general movement of vertebrate animals. Therefore, these muscles are called skeletal muscles. The slow creeping movements of an earthworm are entirely due to muscle activity while the creeping movements in a snake involve the ribs and ventral scales besides the muscles.

For affecting the movement of a skeletal part generally a pair of muscles is necessary. One of the pair, through its contraction distorts the position of the skeletal part generally through flexion. This is the flexor muscle. The other member of the pair, through its contraction restores the skeletal part to its original position. This is the extensor muscle. Thus the two members of the pair work antagonistically for affecting the movement of the skeletal part.

For locomotory movements to be executed in a vertebrate, muscle and skeletal elements alone are not sufficient. The contractions and relaxations of the different muscles at different joints must all be brought into harmony. This is what is called coordination. This is brought about by the nerves involved in the reflexes concerned.

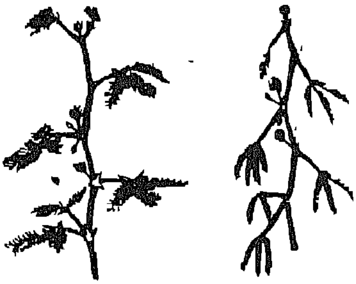

Fig. 23.22 'Touch-me-not' plant : (A) before, and (B) after it is touched

23.6—3 Movement in plants

With the exception of some algal forms almost all the plants are anchored to the soil and are immobile. It is of interest to note that mobility in higher plants is restricted to spores and seeds. Some algal forms, like chlamydomonas and volvox living in water show mobility by means of a pair or more of flagella. In terrestrial plants, namely the Bryophytes, Pteridophytes and Gymnosperms, mobility is restricted to the male cells, namely the spermatozoids. They are ciliated and move about in a medium of water. They show response to changes in temperature, light, etc.

In higher plants, the angiosperms, even the male cells have no motility. They are carried to the vicinity of the egg in the pollen tube formed from the pollen grain. Although it is not always apparent, movement is quite common n higher plants When a flower opens its parts are spread out by a slow movement The leaves of the sensitive plant, 'touch-me-not' fold up when ouched by hand (Fig. 23.22) and open again after some time. The bending of plants towards light is another example of movement. This can be usually observed in seedlings germinating from seeds in the dark. Plants also show corrective movement in response to gravity. The roots usually grow downwards (positively geotropic), the shoot grows upward (negatively geotropic). n whatever manner the germinating seeds are planted the roots and shoots ssume correct positions by curvature.

23.7 Reproduction

One of the important characteristics of living organisms is their ability to reproduce their kind. This is essential for the perpetuation of any species. Each organism, either a plant or an animal, lives for a fixed span of life. Death may take away the individual but the individual maintains its continuity through reproduction. Reproduction is an answer to death Other characteristics of life may have some parallel in the non-living world, but reproduction is a unique character of the living.

23.7—1 Types of reproduction

Living organisms reproduce in two different ways, by (1) asexual reproduction, and (2) sexual reproduction.

In asexual reproduction the same individual multiplies. In sexual reproduction two individuals are invariably involved in reproduction. The offspring arises from the fusion of two cells, one from each parent.

ASEXUAL REPRODUCTION IN UNICELLULAR ORGANISMS

Fission is the most common method of asexual reproduction among unicellular organisms. The organism divides itself into almost two equal

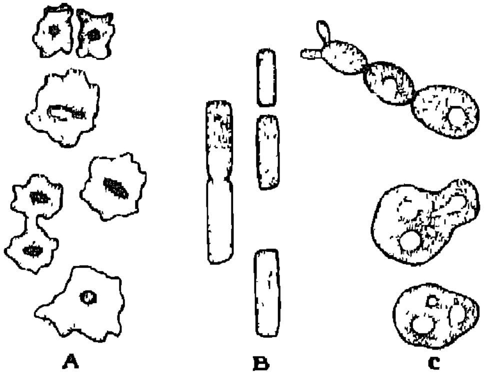

Fig 23.23 Multiplication by asexual reproduction in (A) amoeba (B) bacterium, and (C) yeast

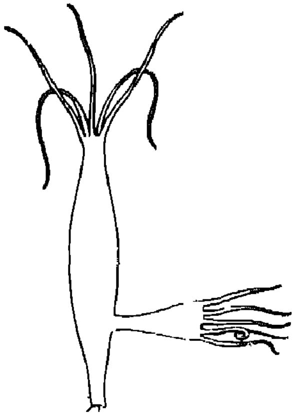

Fig. 23.24 Budding in hydra

halves. Each of these then grows into full size and the process may then be repeated. Bacteria and amoeba reproduce by this method (Fig. 23.23).

Asexual reproduction in yeast cells is accomplished by budding (Fig. 23.23). In the yeast cell a bulbous projection appears. This is known as the bud. The nucleus of the parent cell divides and one of the daughter nuclei passes into the bud. Finally this outgrowth detaches from the mother body. This process of budding is repeated under ideal conditions.

ASEXUAL REPRODUCTION IN MULTICELLULAR ORGANISMS

Budding: The term budding is also used to describe asexual reproduction in multicellular organisms. A bud may be formed in hydra as an outgrowth of the body wall (Fig. 23.24). The bud grows into a small hydra and breaks off from the parent to become a new individual

Fragmentation . In sponges, some coelenterates, flatworms, etc., when a part of the body of the organism is severed, the part can regenerate into a new ndividual.

In the thallus of *Riccia*, and filamentous alga *Spirogyra* fragmentation is very common, where each of the fragments grows into a new individual.

Sporulation : In plants which do not produce seeds, the formation of spores s a common method of reproduction. These spores are light in weight and very small in size. They have thick walls, which enable them to withstand the adverse conditions in the environment. In several algae, a single individual cell produces four to eight motile spores called zoospores. Under favourable conditions each of them develops into an alga. In higher forms of plants these pores are enclosed in a capsule. In some fungi like *Mucor* (Fig. 23.25) spores are produced prolifically.

Vegetative propagation: Ornamental and orchard plants are propagated ommonly by cutting, grafting and layering. The daughter plants produced by hese methods are identical with the parents in all respects.

Grafting: Nurserymen grow mango and orange trees by planting seeds. They aise their seedlings not for their fruit but for a strong root system. When he plant is firmly established the portion of the plant above the ground is emoved. A twig taken from a mature tree of the desired variety (scion), is nserted in a notch in the cut stump (stock) (Fig. 23.26). The successful develop-

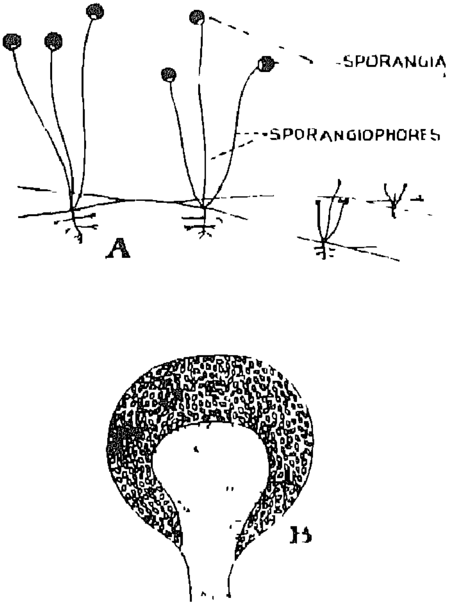

Fig. 23.25 A Formation of sporangia in asexually reproducing mucor B. An enlarged view of a sporangium showing sporangiophore and spores

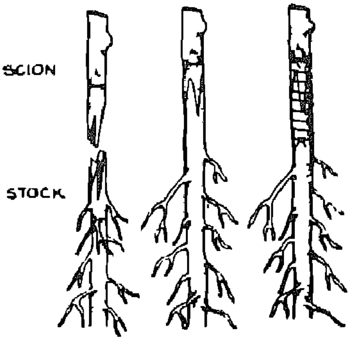

Fig. 23.26 Successive stages of grafting in plant

ment of the graft depends on the accurate mitotic activity of the cambium cells of stock and scion. The scion obtains all its requirements of water and minerals from the root system of the stock. The fruit that will be produced eventually will be identical to the fruit of the tree from which the scion was taken. Grafting is a very common horticultural method of propagation of many fruit trees. The desired fruit qualities are maintained by grafting practices.

Cutting: Propagation by cutting is the only method of propagation in rose, *Coleus*, *Pothos* and bougainvillea plants. When cuttings of these plants are placed in moist soil they strike roots and grow into new plants. Layering is the common method of propagation followed in some ornamental plants, e g. jasmine and rose plants In this method one or more branches of a plant are bent close to the ground and covered with moist soil. Some time later the branches strike roots and produce plantlets. These plantlets can be separated from the parent as new individuals. New plants develop from the leaves of *Bryophyllum* (Fig. 23 27) and leaf cuttings of *Begonia*.

SEXUAL REPRODUCTION IN ANIMALS

In sexual reproduction the offspring arise through the fusion of two specialised cells called gametes. Generally, one of the gametes is active and smaller in size. This is the male gamete. The other gamete is generally passive

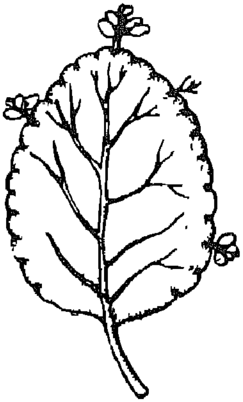

Fig. 23.27 Vegetative propagation from a leaf of *Bryophyllum*. Each of the notches along the margin of the leaf has the potentiality to form a new plant.

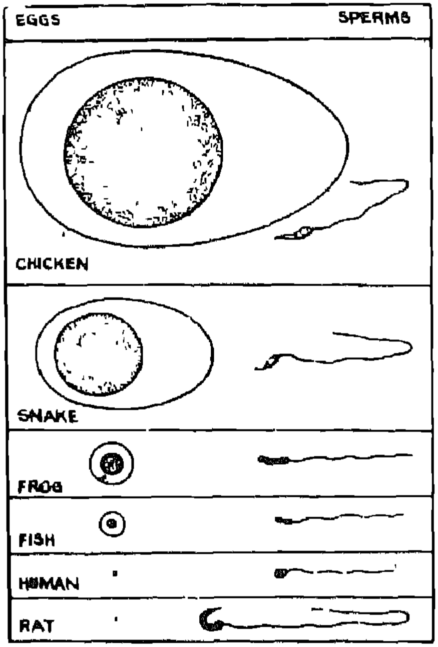

Fig. 23.28 Eggs and sperms of some animals. Note the relative size difference between the eggs of chicken, snake, frog, fish, human and rat.

and larger in size. This is the female gamete or the egg. If an organism produces male gametes alone it is called a male. If it produces female gametes it is called a female. If it produces both the gametes it is called a hermaphrodite. In malarial parasite two individuals participating in sexual reproduction are dissimilar in appearance. So is the case with a cockroach or man. In these cases the individuals are said to be unisexual. But in earthworm and hydra the male and female reproductive systems are present in one and the same individual. Therefore, hydra and earthworm are bisexual. But a given earthworm or hydra produces at a given time only either male or female gametes. Thus at a given time it can behave as a functional male or functional female. Therefore even in these bisexual animals, unless a functional male and functional female are present sexual reproduction cannot take place.

The male gamete is often called the spermatozoon and the female gamete the egg or ovum (Fig. 23.28). The fusion of spermatozoon produced by one individual with the ovum produced by another individual is called cross-fertilization So when the sexes are separate either anatomically or functionally, cross-fertilization is the rule in this kind of reproduction. Naturally the offspring gets the characters of the paternal parent through the spermatozoon and the characters of the maternal parent through the ovum. Thus the offspring looks different from either parent.

The males and females have different sexual characters. They also show peculiar reproductive behaviours. Cross-fertilization is ensured through close approximation of the male and female parents This is possible as the animals are motile. In animals like fishes and frogs the two parents come together and shed their gametes into surrounding water. The spermatozoa fertilize the ova in water. This is called external fertilization. In insects, spiders and mammals the spermatozoa are deposited by the male inside the body of the female. For this purpose the male has an intromitant organ. The spermatozoa fertilize the ova inside the body of the female. This is internal fertilization.

The spermatozoa are very small and active cells which swim about and go in search of the large, passive ovum. To ensure fertilization a large number of gametes are produced by the parents. This is more so when the fertilization is external because the chances of the spermatozoa meeting the egg in surrounding water are less than inside the body of the female.

Though many spermatozoa approach and contact the egg, only one finally fuses with it. The fusion product is called zygote. It is impermeable to other spermatozoa. The spermatozoon and the ovum have each a haploid set of chromosomes, as they are produced through meiotic division. Therefore, the original diploid number of the chromosomes is restored in the zygote. The zygote develops into the offspring.

The development of the zygote may be facilitated, specially in higher organisms by the maternal parts of the reproductive system. These parts act as endocrine glands and secrete the hormones.

SEXUAL REPRODUCTION IN PLANTS

In several angiosperms or the flowering plants the flowers are bisexual or hermaphrodite. They contain both male and female reproductive structures. The stamens produce the microspores or the pollen grains. The ovules in the gynoecium produce the megaspores. The microspores and megaspores are formed in the respective structures after the meiotic division. So they contain half the number of chromosomes of a parent.

Pollen grains (microspores) are carried by various agents like insects, air and water to the stigmatic surface. The male cells are formed inside the pollen grains and they are carried in the pollen tube through the style. The megaspore develops into an embryo sac which contains the egg. The male cell fuses with the egg and forms the zygote. After some time the zygote ultimately develops into the embryo, which in course of time develops into a new plant.

23.8 Growth and Development

You are well aware of the phenomenon of growth. The development of the seed into a mature plant is a remarkable process (Fig 23.29). You have also observed the growth of man or animal from the new born stage towards adulthood (Fig. 23.30). In this context, you must have also noticed that individuals pass from one stage to another during the course of life and show ncrease in size. This entire process of transformation of an individual organism s an important area of biology and is studied under growth and development. The process of growth involves increase in the mass of cytoplasm indicated by cell size and cell number.

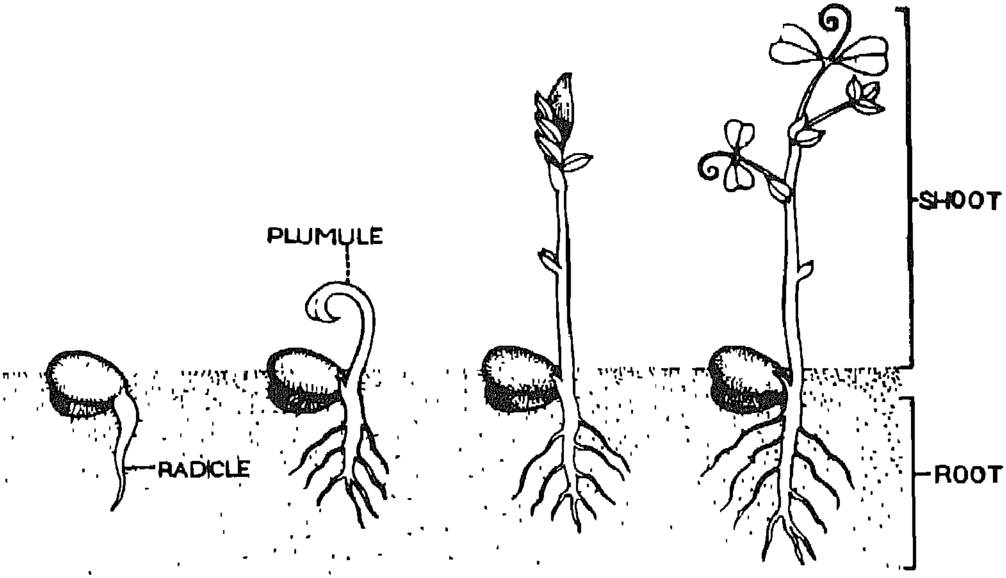

Fig 23.29 Growth and development of a plant

The process of growth and development is remarkable for its orderliness. An organism passes through a well-defined series of events which lead to the sequential development of form and physiology, characteristic of a particular species. A mango plant develops shoot and root system unique to itself with a set type of roots, branches, leaves, flowers and fruits (Fig. 23.31). On the basis of these characteristics you can always distinguish a mango plant from a banana plant. This uniqueness or identity of form, as you know, is due to the distinctive genetic constitution or 'blueprint' possessed by each species and the modifying effects of the environment Similarly, a cow can always be distinguished from a buffalo, no matter how much alike the two may look to be.

A number of characteristics of living organisms are influenced by the environment. Despite the same genetic constitution, the forms of similar organisms raised in different environments may differ significantly. For example,

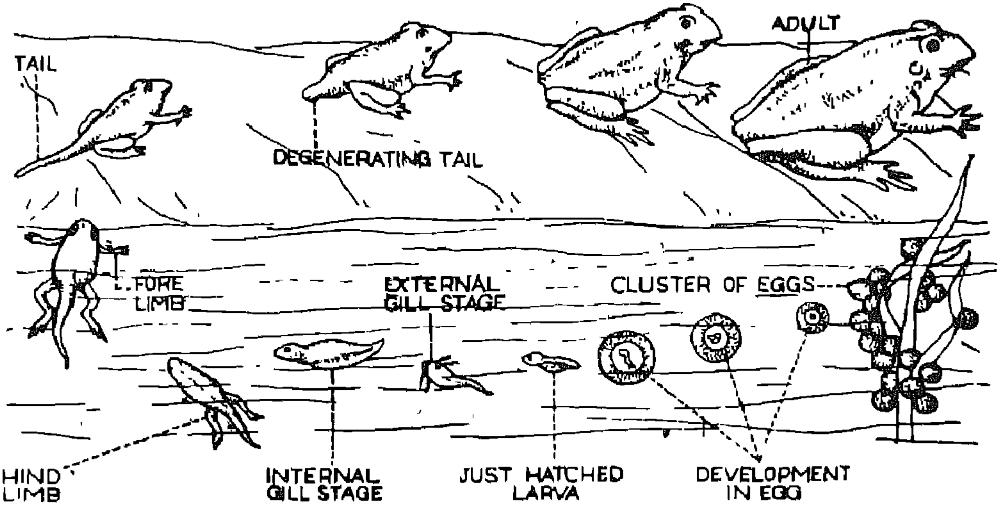

Fig. 23.30 Development of frog

a plant grown in shade will differ significantly from another of the same variety grown in light. As a matter of fact, variation in any of the major factors of environment will bring about noticeable differences in the form and physiology of organisms. This applies to all organisms but is much more pronounced in plants. You can thus generalise that the overall form of an organism is the result of interactions between its genotype and the environment in which it grows.

You are already aware of the different types of reproduction in the living world. In the unicellular organisms, the daughter individual synthesises new materials and develops into an adult. In the multicellular organisms, where sexual reproduction occurs, development begins from the single-cell stage called the zygote. From this single cell stage, through a series of events, the adult form appears. Such changes continue even after germination in plants and hatching or birth in animals.

You know that in the animals like cow, cat, tiger and man, the embryo develops inside the body of the mother. In other groups like fish and frog, the development takes place in the external environment. In birds the develop-

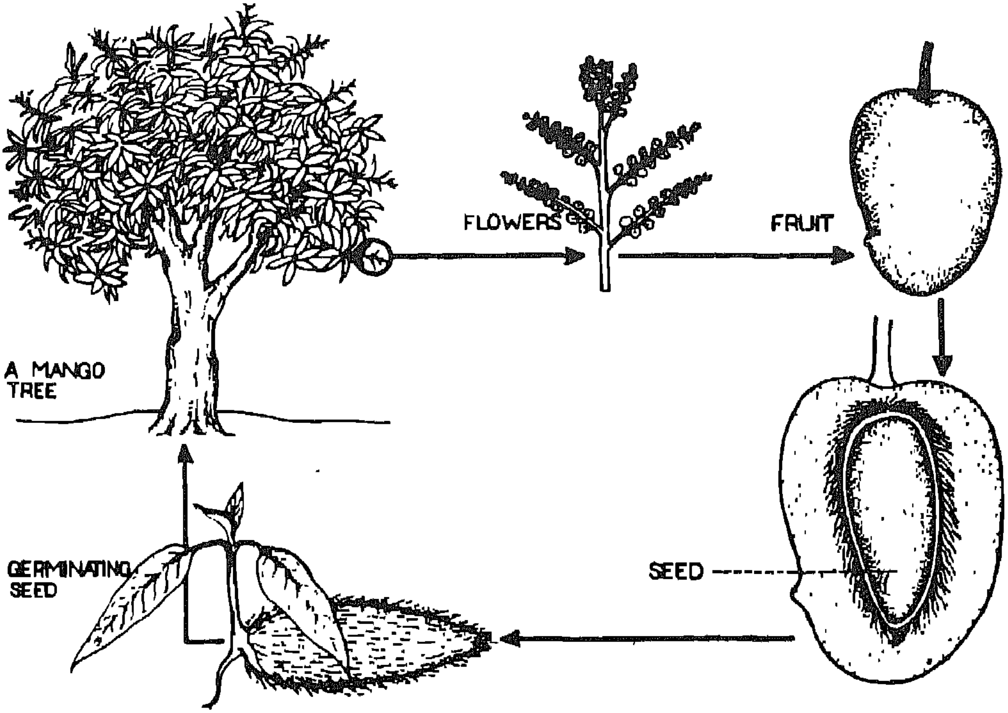

Fig 23.31 Life cycle of a mango tree

ment within the egg is external but it needs a specific temperature. Such temperature is provided by the parent birds, who alternately sit on the eggs. This is called incubation.

Fig 23.28 shows the structure of the egg cells in frog, hen and man. Is it not interesting that all animals have more or less a common and simple beginning ? In the early stages of development, the embryos of different animals look alike. The diversity appears only in the later stages of development. What evidence is provided by these fundamental similarities of embryonic stages? Can you guess ? How are the different organs produced from a single cell ? How are the different organs formed in particular position ? The answers to all these questions depend upon the physical basis of development.

Only in recent years man has been able to understand this basis of development. It has now been understood that all changes during the development are essentially cellular events. It is of interest to note here that the unifying feature of plant and animal structures lies in the basic cell structure. There are five phases of cell development. They are (1) cell division; (2) cell elongation or extension; (3) cell movement; (4) cell differentiation, and (5) cell death.

Of these five, cell elongation is entirely a feature of plant development. It is now understood that changes do not cease with the birth of the new individual. If you look at the photographs of your childhood, you will find that you have changed a lot You know well that you will change further. All these changes are due to cellular activities. Therefore, the scope of the study of development does not end with the study of embryonic or larval stages. It includes the entire span of an individual's life from the formation of germ cells to the death of the individual. Similar cellular events are repeated during regeneration. For this reason the regenerations of different animals (Fig 23.32) ire extensively studied to understand these cellular events. You may like to know about each such cellular event.

'3.8—1 *Cell division*

The essential requisite for the development of an individual is the pro- feration of cells. The cells proliferate by cell division called mitosis. The ite of mitosis is high in the early stages of development. Upto a stage, mitosis also synchronous, that is all the cells divide at the same time. Gradually ie occurrence of mitosis becomes irregular, that is the cells in some parts vide rapidly than those in other parts. In plants, mitosis operates almost roughout the life in the growing stem and root apices. But in animals, here growth is restricted, the occurrence of mitosis is also restricted. For ample, in an adult man, mitosis takes place in the epithelial tissue of skin, gestive and reproductive tracts, in the bone marrow to form blood cells and the testis and ovary. But in most other parts, the same cell continues to rk without replacement. The factors underlying cell division are not yet npletely understood.

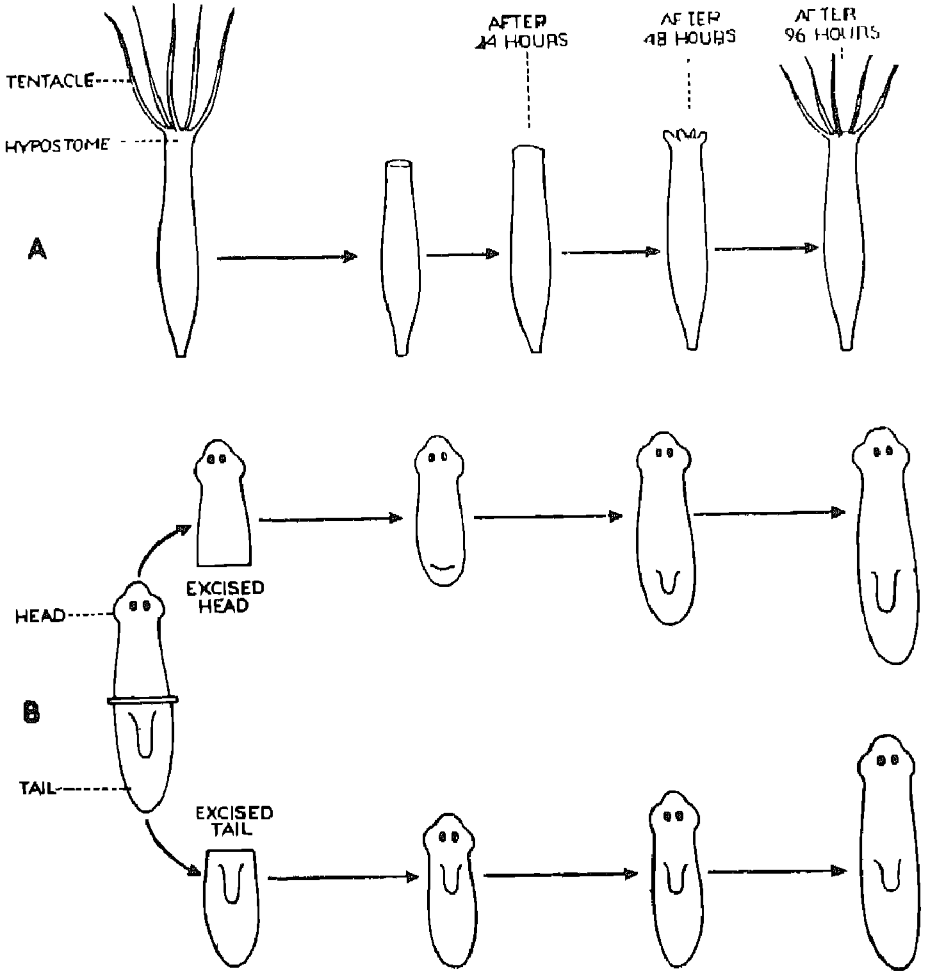

Fig 23.32 Regeneration in (A) *Hydra*, and (B) *Planaria*

23.8—2 Cell elongation

This is found most commonly in plants. After the cell division, the surface area of the cell increases considerably for growth to take place. The cell absorbs water and stretches the already softened cell wall. Along with the stretching of the wall, a new cell-wall material is synthesised. The surface area of the wall is increased. In the case of plant cells, therefore, water absorption and synthesis of cell wall are the important aspects of cell elongation.

23.8—3 Cell movement

During development, considerable movement of cells takes place. These movements are called morphogenetic movements because they are responsible for the development of the forms. Through this movement, the cells take up their proper position to develop further. Cells that are destined to form the face move to the anterior and while cells destined to form the tail move to the posterior end. Thus the cells are sorted out and transported to their destinations. These movements are integrated in space and time. A group of cells move to the right place at the right time so that it can interact with another group. One of the most important tissue interactions is called induction. By induction we mean influencing and changing the fate of a group of cells for proper development. How can the cells identify their positions ? How exactly the cells move ? Why do not they move after reaching their destined site ? These are a few of the many unanswered questions about the cell movement.

23.8—4 Cell differentiation

In a developing embryo, all the cells change and attain a particular form to perform specific functions. This transformation is called *cell differentiation.* A cell, once differentiated, that is, once it has become either a muscle cell or a nerve cell, looses its power to be transformed into any other cell type Why does a cell differentiate ? In plants the cells derived from the meristematic tissue undergo differentiation in structure and function like the palisade cells specialised for photosynthesis or the conducting tissue specialised for translocation. Can a cell, destined to be a muscle cell, change into any other cell type ? The scientists have been trying to solve this riddle of cell differentiation for quite some time.

23.8—5 Cell death

The young cells become mature in the course of time, perform their function and ultimately die. These dead cells are replaced in the individual by new cells. Thus a large number of cells die even when the individual is alive. You never feel that almost every day hundreds of cells of your skin are sloughed off and are replaced by new cells. Your old blood cells are replaced by new ones after every six weeks Such cell death also occurs during development. It is now understood that ageing and cell death is a necessary part of the development cycle. In the case of a few trees they have the capacity to survive for ages, well over a few thousands of years. Plant tissues grown in culture solutions under controlled conditions survive for several years.

23 8—6 Growth in plants and animals

The growth in all living organisms follows a set pattern. Initially the growth is very slow which is followed by a rapid phase. After the rapid phase, the growth rate slows down and after some time no growth is observed.

You may select some flowering plants in your home or school garden at very early stages of growth. Measure their lengths every week. Plot a graph of the length against time

Let us follow the growth pattern of a plant or an animal from the initial to the final stage. If we plot its size at various time intervals, we find the growth-curve shows a typical 'S' shape and is called a sigmoid curve. This curve is typical of all cells, organs, organisms, populations of plants or animals and men (Fig. 23.33).

The growth in all organisms occur in length, breadth and in weight. The plants continue to grow throughout their life but in animals this growth is restricted. Growth in plants is described as unrestricted. It may be noted that there are two active regions of growth in the plants, these are located at the stem and root apex. In the beginning, the growth is uniform. But gradually, the growth becomes irregular and results in a disproportionate body. In the course of growth, the specific proportion of the body is again restored. In both plants and animals, most aspects of growth and differentiation are under specific control of chemical substances. These chemicals are called hormones The hormones occur in extremely small quantities, exert their regulatory effects and are transported from the site of synthesis to the place of action. You are already aware of the different hormone-producing endocrine glands in animals. The plants have four major classes of naturally occurring

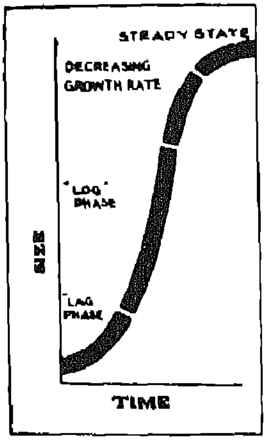

Fig. 23.33 All cells, organs, organisms and populations describe a 'S' or sigmoid growth rate

ormones or growth regulators, these are auxins, gibberellins, cytokinins and bscisic acid. The modes of action of growth regulating substances are complex nd interlinked with each other. The orderly growth and development of e plants and animals is regulated by the growth hormones present in them. part from these factors, environmental factors like light, water and temperaire exercise considerable influence on growth and development. The hormones rve as a link between the environmental factors and the genetic constitution r the blueprint of the plant or animal.

3.9 Control and coordination

You have studied that each living organism carries out a number of vital tivites. For each function there is a system made up of several organs. ach organ, in turn, is made up of thousands of cells. Though functions are vided, when you come to the cellular level, you find that all cells carry out e functions like nutrition, respiration and excretion. Moreover, an organism an individual meets various stimuli from the environment. The response ust be given as a whole. For effective living, each individual must have vices to control and coordinate different activities.

In the unicellular organisms, the single cell while carrying out the vital activities also controls and coordinates them. It shows positive response to some stimuli (gets attracted towards food) and exhibits negative response to some (moves away from harmful objects). The multicellular organisms have a separate system to carry out these functions. In plants, this coordination is entirely chemical but in animals, to kinds of coordination—*chemical coordination* and *nervous coordination*—are present.

23.9—1 Chemical coordination in animals

Hormones control the growth and development in all animals. In insects a number of hormones which control the changes during development are

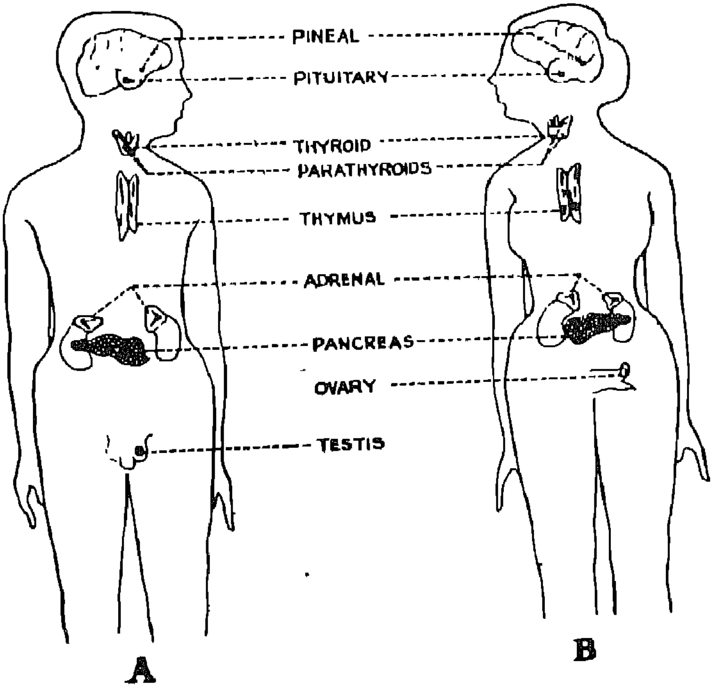

Fig 23.34 Location of various endocrine glands in (A) male, and (B) female bodies

known. Fig 23.34 shows the different endocrine glands in man. All these endocrine glands work in unison and the effect of one is linked to that of the other. Moreover, all endocrine glands work in close cooperation with the nervous system. Before entering into the details of the functions of hormones in animals, let us discuss some other kind of chemical coordination which exsits in animals. You have learnt in the earlier chapter on respiration that during a strenuous exercise, the muscle cells liberate energy. Rapid use of oxygen by these cells causes incomplete breakdown of the reserve substances. Such incomplete breakdown results in the formation of a chemical substance called lactic acid. The increased concentration of lactic acid tends to alter the pH of the blood and thus it stimulates the nerve centre. This stimulation excites the rate of breathing and excess oxygen is supplied to complete the breakdown. Lactic acid is one of the many chemicals which operates within the body of an individual.

HORMONES

Hormones vary greatly in their chemical composition. Many of them are steroids; but some may be proteins and even amino acids. Each hormone creates specific physiological influence on different cells to bring about a particular response. Some hormones are accelerative, some inhibitory. For the normal working of the body, a particular hormone is needed in a specific quantity. The growth will be modified if the quantity increases or decreases. One type of gland produces a hormone or hormones for different functions. For example the pituitary gland produces hormone to control growth and sexual maturity. The same gland, immediately after the child birth activates the flow of milk in the breasts of the mother. Different hormones in vertebrates control important life processes like growth, development, formation of skeleton, digestion and reproduction, whereas, in the invertebrates they control moulting, metamorphosis and migration.

Hormones from the endocrine glands are poured directly into the blood stream. They flow all over the body, but affect only the cells of a specific region. How does a cell identify the hormone which is meant for it ?

For a long time scientists could not make out how this is done. The answer came with the understanding of the role of a chemical substance called cyclic AMP (adenosine monophosphate) in the cell.

TABLE 23.2

Important Hormones Produced in Mammals and their Principal Effects

Hormone	Produced by	Affects principally
Thyroxin	Thyroid	Growth and metabolic rate
Insulin	Pancreas	Sugar metabolism
Adrenalin	Adrenal medulla	Blood pressure
Follicle stimulating hormone (FSH)	Pituitary	Ovarian follicle
Luteinizing hormone	-do-	Ovary, corpus luteum
Growth hormone	-do-	Growth
Anti-diuretic hormone (ADH)	-do-	Kidney-urine volume
Oestrogen	Ovary	Female organs
Testosterone	Testis	Male organs
Adrenocorticotropic hormone (ACTH)	Pituitary	Adrenal cortex

23.9—2 Nervous coordination

You are already familiar with the general organisation of the nervous system. The nervous system not only controls the working of the internal organs, but also the response to the external stimulus. It has the following components:

1. *Receptor organs* to act as the entrance of different stimuli (can you name some receptor organs ?).
2. *Sensory pathways* to transmit messages to the receptor (what are the different kinds of messages which we receive ?)
3. *Modulators* to receive messages and to issue specific instructions (name the modulators in man).
4. *Motor pathways* to carry instructions from the modulators to the different parts of the body for necessary action.

The different muscles and glands which work according to the instructions are called *effectors*.

You are already familiar with the appearance of cells which constitute the nervous system. The nerve cells or neurons are generally star-shaped or spindle -

shaped. Each cell has one long fiber called axon and several small fibers called dendrites. The dendrites of one neuron remain in close contact with the axon of a neighbouring neuron. These regions of contact are known as synapses. The innumerable synapses between the millions of nerve cells form the basis of the nervous system. The most important organ of the vertebrates is the brain. This organ has attained maximum growth and complexity in man. It has been possible today to map out different parts of the brain according to their function. But all the regions are interlinked and the coordination of different works is done in the brain itself.

REFLEX ACTION

Many functions go on inside our body without the participation of the brain in response to external stimuli. These are called reflex actions. This way many of the functions are carried out in the body without the knowledge and participation of the brain. These reactions are not initiated by the spinal cord but are effected only by the response due to an external stimulus. When the finger is burnt on a flame or when you suddenly step on a sharp object you withdraw your finger or leg immediately. How does this happen ? In the reaction messages are flashed along the nerve to the spinal cord The spinal cord in turn stimulates the nerve supplying the muscles of the arm or the leg. This results in the contraction of the muscles, pulling away the hand or the leg. These reactions are performed in a fraction of a second. The path travelled by the impulse from the sensory organ to the motor organs is called the reflex arc. The nervous response is involuntary and it occurs even before you are aware of the stimulus. In your daily life many actions are carried on involuntarily. These are known as reflex actions.

Most reflex arcs are much more complicated. They involve many more components. There can be chains of reflexes. Most of the reflexes are mediated in the spinal cord itself. Then they are called spinal reflexes. It does not mean that there are no reflex arcs in the brain. For example the wink reflex of the eye lids is the one mediated by a reflex arc in the brain.

How are the messages conveyed through the nerves ? For a long time two sets of answers were provided. According to one group, this happened due to a change in the electric charges, but the other group holds that this is due to chemical reactions. The advent of electron microscope and introduction of new techniques have helped answer this question correctly. It is now regarded to be an electro-chemical process. When the neuron is stimulated, the message flows as a change of charge, but when it is transferred from one neuron to the other, it passes as a chemical substance.

23.9—3 Chemical coordination in plants

In addition to water, light, carbon dioxide and nutrient elements a plant requires other chemicals for its growth. Different aspects of plant development, growth, leaf fall, flowering and the like are controlled by certain organic substances known as plant hormones. Hormones are considered as one of the most important cell coordinating substances in plants.

A hormone is often described as an organic substance, normally effective at very low concentrations, that is produced at one locus and may then bring about its profound effect elsewhere. There are four main groups of plant hormones and these are *auxins*, *gibberellins*, *cytokinins* and *abscisic acid*. It is the overall balance of these four groups of substances that influences the manner of cell division, cell enlargement and cell differentiation in plants.

AUXINS

One of the representatives of this group of substances is *indoleacetic acid* (IAA). Several other compounds have been synthesised in the laboratory, which have auxin like properties, like 2,4-D (2,4-dichlorophenoxy acetic acid), NAA (naphthalene acetic acid) which are commonly used in agricultural and horticultural practices as weedicides in extremely low quantities. The auxins are being used in rooting of cuttings and controlling premature fruit drop in orchards. They have several uses in horticulture. When unfertilised flowers are sprayed with IAA, seedless fruits can be obtained.

GIBBERELLINS

They are also growth substances. The effects of the gibberellins are particularly noticeable on the dwarf strains of plants. Genetically dwarf strains of pea, corn or bean can be stimulated to grow to the size of tall plants by the application of gibberellins at low concentration. They also promote seed germination.

CYTOKININS

Cytokinins play an important role in the expansion and differentiation of leaf tissues. They influence the rate of mitosis and are present in young developing tissues. They cooperate with other plant hormones in regulating growth and development.

ABSCISIC ACID (ABA)

This has been discovered recently. Unlike the other hormones it is a very good example of a hormone that primarily acts as a growth retardent or suppressor of growth. In the life of the plants it promotes leaf fall, regulates stomatal aperture thereby controlling water loss, in inducing bud dormancy and such other phenomena. ABA is the most potent of all the growth hormones.

In recent years plant growth regulators are being used increasingly in rooting of cutting, control of pre-harvest fruit drop, control of flowering in the production of seedless fruits, weed control and several other useful operations in agriculture.

EXERCISES

1. What are the important chemical components of food ?
2. Give five examples of each of the following.
   (i) Autotrophs; (ii) Saprozoa; (iii) Parasites; (iv) Herbivores (v) Carnivores, and (iv) Omnivores.
3. What are the important steps of holozoic nutrition ?
4. Name the enzymes, in serial order of their action, which affect the following components of food
   (i) carbohydrates; (ii) protein, and (iii) fat.
5. Indicate the changes in the food that take place in the small intestine.
6. What is the site of photosynthetic reactions ?
7. What is the relation between chloroplast pigments and light ?
8. Describe an experiment to prove the necessity of chlorophyll for photosynthetic activity.

9 How does respiration differ from breathing ? What is the difference between respiration and combustion ?

10. What are the major steps in respiration ?

11. What is the pivotal or important intermediate compound produced in respiration ?

12. What are the end products formed in aerobic and anaerobic respirations ?

13. What are the different kinds of transport systems found in the living organisms ?

14. Name the substances which are carried by the transport system in man.

15. What are the various components of blood ?

16. Name the substances that are translocated through xylem and phloem ?

17. Describe an experiment to demonstrate the ascent of sap in plants.

18. Why is the process of excretion important for living organisms ?

19. How do plants get rid of the metabolic wastes ?

20. Name the waste products that are formed in the plants during photosynthesis and respiration.

21. What are the different excretory products of man ?

22 What are the various organs of excretion present in man ?

23. What is the need of locomotion in animals ?

24. Name the structures concerned with locomotion in the following .
(i) Amoeba; (ii) Paramoecium; (iii) Earthworm; (iv) Insect; (v) Fish; (vi) Reptile; (vii) Bird; (viii) A Mammal.

25. What are the structures that show movement in higher plants ?

26. Name any two movements shown by plants in response to light and gravity.

27. Put a (√) mark against the correct statements.
  (i) Reproduction is an essential life process (   ).
  (ii) Reproduction occurs only in animals (   ).
  (iii) Sexual reproduction is seen only in higher organisms (   ).
  (iv) Reproduction is not necessary for the individual but important for the population (   ).
  (v) Sexual reproduction involves participation of two individuals (   ).

28. What are the different types of asexual reproduction ?
29. Why is cross-fertilization more important than self-fertilization ?
30. What do you understand by hermaphrodite? How does cross-fertilization occur in hermaphroditic forms ?
31. What are the essential requisites for sexual reproduction ?
32. What are the importnat features of growth in a plant ?
33. How does animal growth differ from plant growth ?
34. What is the significance of cell death and cell movement in development ?
35. What is cell differentiation ? Explain with an example.
36. What is the nature of substances which control the growth in plants and animals ?
37. Describe why a living organism has devices to control different life activities
38. How does a unicellular organism control its activities ?
39. Name the different plant hormones ?
40. Mention the functions of the following hormones :
    (i) Auxin; (ii) Gibberellin; (iii) Cytokinin; (iv) Abscisic Acid;
    (v) Thyroxin.
41. What is the role of hormones in the invertebrates ?

Chapter 24

Genetics and Evolution

24.1 Heredity and variation

You have already learnt about the living cell, organisation of a living body, its relations with the environment and various life processes. You also have some basic ideas about the chromosomes and heredity You know that though the members of a species give birth to their own kind, the offspring show some dissimilarities to their parents and to each other These dissimilarities in related organisms are called 'variation'. What causes this difference between two individuals related by descent ?

24 1—1 Causes of variation

Before we proceed to find answer to this question, it is essential to bear in mind that though all organisms appear different from each other, they are strikingly similar in a number of biochemical processes In other words, all organisms are similar at molecular level, for the molecules which make them are essentially alike. When we talk of variation we are mainly concerned with variations in morphological. anatomical, reproductive and behavioural characteristics of organisms.

Let us analyse the gross external appearance and the factors that are inherited. You know that the genes are the hereditary units and that they are transmitted to the offspring during reproduction. The genetic constitution of an individual is called *genotype*, while the external appearance, anatomy, behavioural pattern and reproduction make the *phenotype* of an organism. After birth, the young ones grow in a particular environment. A change in environment may influence their appearance or phenotype. But the overall morphology or anatomy, however, remains similar to that of the parents. The environment, usually has no influence over the genotype. The phenotype, in other words, is the net result of interaction between genotype and environment.

It is obvious from the above that variation may be due to environment or heredity. In order to understand this, you may try the following experiments These experiments will take a long time. You should make periodic observations.

EXPERIMENT I

1. Take some pea plant seeds of pure breed which produces only white flowers and yellow, round seeds.
2. Divide them into three sets.
3. Sow the first set of seeds in a normal way in your garden. This is your control experiment.
4. Sow the second set at a place free of weeds, well manured and open. Water the young plants once a day.
5. Sow the third set at a shady place infested with weeds and lacking manure. Water the young plants once in two days
6. Let all the plants grow, bear flowers and seeds.
7. Record your observations.

Now analyse what you have observed. What are the colours of flowers and texure of seeds produced by the different sets of plants ? What difference do you find in the overall appearance of these sets of plants ?

The colour of the flower and texture of the seed are characters which remain grossly the same. Different conditions have not affected the genotype. However, the sizes of the flowers, seeds, leaves and the plant as a whole have changed in different conditions. The same genotype, therefore, may produce slightly different phenotypes when subjected to different environmental conditions of food, temperature, light, humidity, etc. This is a case of environmental variation. However, such variations are not inherited.

EXPERIMENT II

1. Select a few seeds of maize, wheat, gram and pea.
2. Select a plot which is free of weeds, well manured and open.

3. Sow all the seeds in the selected plot and water regularly.
4 Record your observations.

You will find that the growing plants could be grouped into four types: maize, wheat, gram and pea. Each group has its own distinctive characteristics. The same is true of man, dog, dove and bull. Such differences arise due to different genotypes. But what about the individuals within the same species ? Brothers and sisters of the same family look different; the pups are different from their parents and also from each other. Similarly, we find differences among different varieties of mangoes, wheat, pea and a number of other plants.

Variations among different species arise due to a gross difference in genotypes, while variations within a species result from the reshuffling of genes during meiosis and mutation You know that during meiosis, the exchange of parts of chromatids result into genetically altered chromosomes. Thus, genetically, the daughter nuclei are not exactly similar to the parent nuclei. When two such nuclei fuse to produce a zygote, the genetic constitution of the zygote would be different. Such a zygote would grow into an individual which bears similarities to parents in gross structure, but differing in some details.

The hereditary variation may also be due to the varying number of chromosomes. You know that the number of chromosomes and the total number of genes for a species are always constant. If the number of chromosomes changes, either naturally or artificially, the resulting offspring would grossly differ from its parents. The following example will explain this.

The ancestor of the wheat varieties cultivated now had a chromosomal complement of seven pairs The present varieties of wheat have 14 and 21 pairs. This means that doubling or tripling of the chromosomal number has given rise to different varieties of wheat. This is true with many other plants. Such a phenomenon is little known among animals.

Another type of chromosomal alteration is also known. The chromosomal complement of man, for example, is 23 pairs. If there is an increase or decrease in the number of chromosomes of any one of these pairs, the phenotype is altered considerably and is distinct from its parents. In *Datura* (a poisonous plant), the chromosomal complement is 12 pairs. But often in several forms of *Datura*, the chromosome number is found to be increased. Such plants with changed chromosomal complement bear different phenotypic expression.

re also caused by mutation of genes, that is, an
-lf. Hereditary disorders like colour blindness,
due to gene mutations. The gene responsible
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ite flowers; round vs. wrinkled seeds; etc.
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haracters that they represent. His method thus
ıe track of characters of plants of several
ross; and (3) drawing generalisations on the
ps between the hybrids having contrasting

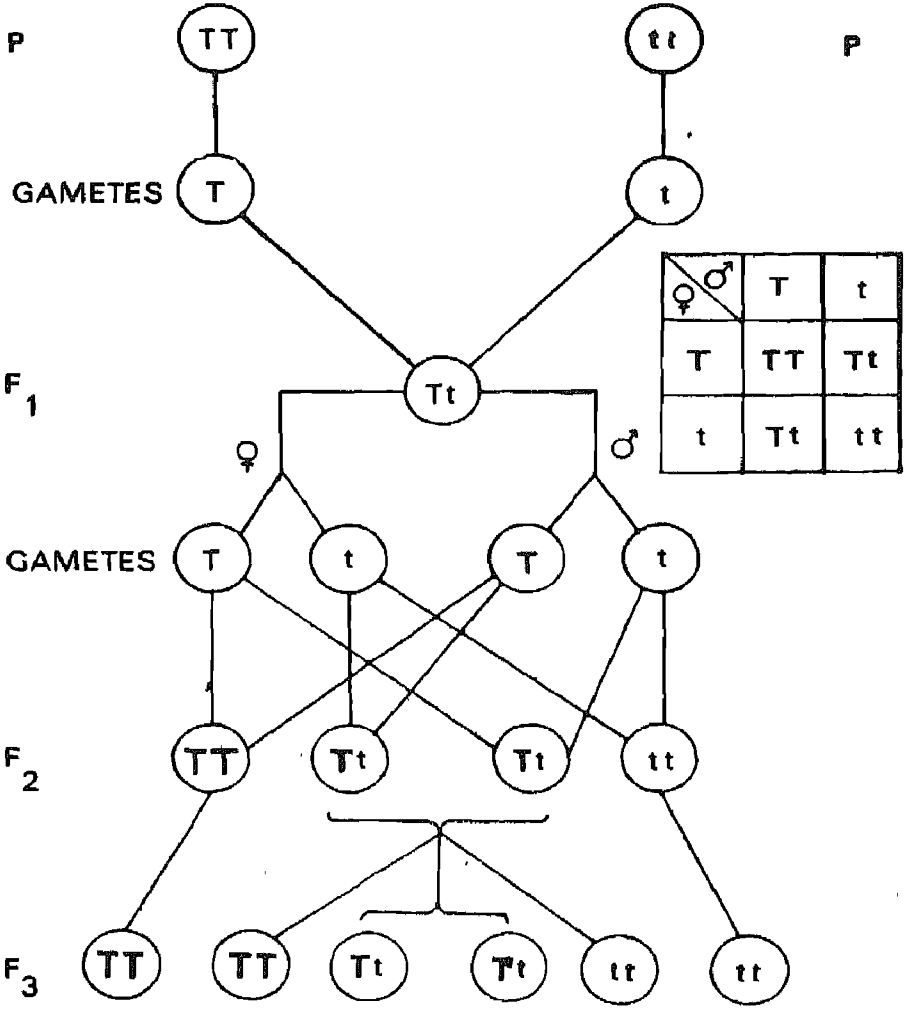
ınce of a single pair of characters and later took combinations of pairs of two or more characters His methodology contributed a great deal to his success and still serves as a classic example of scientific methodology.

24.1—2 Monohybrid cross

The monohybrid cross refers to the hybridization experiments involving a single pair of contrasting characters. Mendel selected two sets of pea plants. One set consisted of tall plants (200 cm and above in height) and the other of short plants) upto 50 cm in height). He first made it certain that seeds from tall plants invariably produced tall plants and the dwarfs produced only the dwarfs in successive generations, that is, they were true to their types or true breeding. He then cross-fertilised the tall plants (P) with dwarf plants (P) (P in the parenthesis denotes parental generations). In order to achieve this he removed the stamens at an early bud stage and dusted the pollen of a dwarf plant over the stigma of the tall plants. He also made 'reciprocal crosses' so that each set had a chance to set as male or a female parent. He collected all seeds upon ripening and raised the 'hybrids' from these seeds. He referred to this generation as F_1 or the first filial generation. You will be surprised to know that all plants of this generation were tall. He then raised the next generation of plants with seeds collected from the F_1 generation after crossing the individuals of this generation between themselves. You would probably think that this generation (F_2) would also consist of tall plants only. But Mendel noted that this F_2 generation of plants instead of consisting of only tall plants, had 75 per cent tall plants and 25 per cent dwarf plants, that is, a ratio of 3:1 was observed. It was found that the dwarf of F_2 generation when self-pollinated were true breeding, while of the tall plants only 25 per cent were true breeding. The remaining 50 per cent of the tall plants, in the next generation, produced tall and short plants in a ratio of 3:1. His plan of work is presented in Fig. 24.1.

Mendel explained his results in the following way. He suggested that each parent contributed a 'factor' to the offspring. This factor was later termed as *gene*. The F_1 hybrids were all tall because the factor contributed by the tall parent was dominant over the factor of dwarfness. He suggested that though both the characters were present in the F_1, the dwarf character remained unexpressed as it was masked by the character for tallness. In the F_2 generation, however, characters segregated and produced tall and dwarf plants.

On the basis of these observations, Mendel postulated the 'law of segregation,' which stated that the pairs of contrasting character of a hybrid separate from ach other in subsequent generations.



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T	TT	Tt
t	Tt	tt

Fig. 24.1 Mendel's Monohybrid cross

It is important for you to familiarise yourself with certain terms which find place in the literature of genetics and their origin can be linked to Mendel's work. A pair of contrasting character is observed due to the presence of two *alleles* of a gene which govern the expression of that character. A true breeding individual has identical alleles, for example, a true breeding tall pea plant has alleles for tallness only (TT) while a true breeding dwarf has alleles only for dwarfness (tt) (Fig. 24.1). Such a true breeding individual is *homozygous*, in contrast to a hybrid, which has two different alleles for a particular character. Such an individual is referred to as *heterozygous* (Tt) The *phenotype* refers to the external appearance of an individual, for example, Mendel's F_1 plants were phenotypically tall. The internal genetic constitution of an individual is referred to as *genotype*, for example, the heterozygote (F_1) had the genotype of Tt and was genotypically different though phenotypically similar to the homozygote TT. In genetic terminology, allele 'T' for tallness is known as *dominant* over the allele 't' for dwarfness which is called *recessive*.

You can now proceed to attempt the modern explanation for Mendel's experiment on the basis of the genetic constitution of the individual plants. Fig. 24.2 illustrates the crosses.

The two parents were true breeding tall and short plants and each formed single type of gametes. The gametes each from either of the parents, fused to form the heterozygote of the F_1 generation, the plants of which were phenotypically tall but contained the allele of dwarfness as well. This heterozygote formed two types of gametes which fertilised each other to form the plants of the F_2 generations which were either tall or dwarf in a phenotypic ratio of 3:1 (tall : dwarf). Genotypically, half of these plants were tall and dwarf homozygotes, while the rest were heterozygotes like the F_1.

24.1—3 Dihybrid cross

After the study of a single pair of contrasting characters, Mendel started to work on pea plants with two or more pairs of contrasting characters. A cro between two sets of plants involving two pairs of true breeding contrasti characters is referred to as a *dihybrid cross*.

For this cross Mendel selected a set of plants which were true br for yellow and round seeds and another set which always produced and green seeds. In the F_1 generation of the cross, he observed t

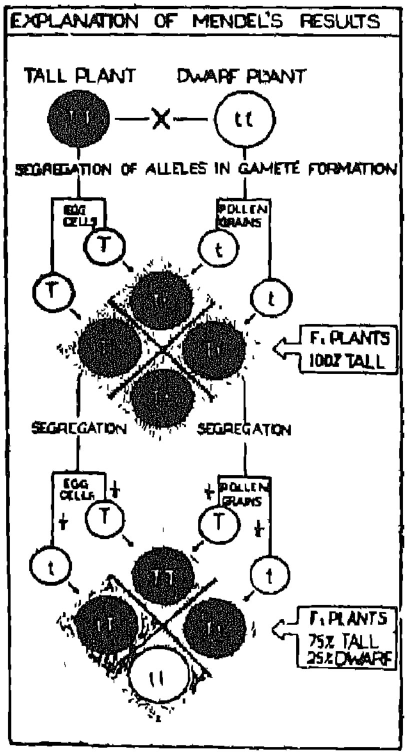


Fig. 24.2 Explanation of Mendel's results

lants produced only yellow and round seeds. You would expect this on the asis of the dominance of the characters which you have already studied above. Vhat did it mean ? Which characters were dominant and which were recesive ? The F_2 generation of these plants produced four phenotypes of seeds : 1) round and yellow; (2) round and green, (3) wrinkled and yellow; and 4) wrinkled and green. The ratio between different phenotypes was in the spective order of 9:3:3:1. In order to account for the behaviour in the F_2 neration, Mendel suggested that when two pairs of contrasting characters me from the same parent they may not necessarily stay together but behave as if each character is an independent unit. This laid the foundation for Mendel's second law of 'independent assortment' which states that when two pairs of characters are contributed by the same parent in a cross, they assort independently of each other in future generations as independent factors.

On the basis of the genetic diagram of the monohybrid cross, try to prepare a diagrammatic account of the dihybrid cross with the help of your teacher.

All these significant experiments of Mendel though performed in the middle of the last century, remained unknown till the beginning of this century. After their rediscovery, the significance of these studies were realised and experimentation followed on a large scale throughout the world. Mendel's work and his laws formed the basis of the concept of genes. The gene, as you know, is the focal point of the science of genetics. The researches in genetics have led to several improved varieties of crops and animals. They have also helped us in understanding the causes of several serious diseases

24.2 Basis of heredity and its mechanism

It must be clear to you by now that genes are hereditary units. You also know that they are located on chromosomes and are carried along with them during cell division. In recent times a large number of biologists and biochemists have taken much interest and have contributed towards the understanding of life at the molecular level The structure and functions of genes as chemical substances have been worked out in details.

A chemical analysis of an organism would reveal its chemical composition. A large number of elements go into its make-up. Some of the most common elements are carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur. Some of these elements make the various organic molecules like fats, carbohydrates, lipids, amino acids, purines and pyrimidines. Some of these molecules join together to form a complex unit called 'macromolecule'. For example, a large number of amino acids join together by specific chemical bonds to form the giant molecules of proteins. Another example of macromolecules is the nucleic acid. A nucleic acid molecule is a polymer of nucleotides, each of which is composed of a 5-carbon sugar, phosphorus, and a purine or a pyrimidine base. Purines and pyrimidines are nitrogen-containing organic molecules. On the asis of the type of sugar, whether deoxyribose or ribose, the nucleic acids have een distinguished into deoxyribonucleic acid or DNA and ribonucleic acid or NA, respectively. The chemical analysis of chromosomes has shown that ey are made of proteins and nucleic acids. Since it is the chromosome which arries the genes it is necessary to know what part of chromosome carries the ereditary information.

It has been proved experimentally that it is the DNA part of a chromo- me which is responsible for heredity. The second type of nucleic acid, the NA does not take part in the inheritance of characters. The RNA generally not found in the chromosomes. However, the genetic material of some plant d bacterial viruses is RNA In higher organisms, the RNA is abundantly und in the cytoplasm in special particles called ribosomes and it is also found thin the nucleolus. In all organisms, the DNA synthesises the RNA to gulate the cell metabolism.

2—1 Chemical structure of nucleic acids

We have already discussed the various components which form a macro- lecule of nucleic acid. These molecules are with purine and pyrimidine ses, pentose or 5-carbon sugars and phosphates. A base, a sugar and a osphate molecule, when join together, form a unit known as a *nucleotide*. large number of such nucleotides join to form a polynucleotide chain known nucleic acid. In the case of RNA, it is a single chain. But in the DNA, it lways a double chain. In this double chain of DNA, the bases of one chain joined with the bases of the other, forming a ladder-like structure (Fig. 3). This molecule is further twisted in such a manner that it looks like a ble helix (something like a spiral staircase). The type of sugar that is found he DNA is deoxyribose. The purine bases found in the DNA are adenine guanine. The pyrimidine bases are cytosine and thymine. One chain of A is complementary to the other. An adenine base of a chain always pairs thymine of the other, while guanine of one strand always makes a pair cytosine of the other.

The RNA differs from the DNA in being a single-stranded chain of poly- eotide and in having the ribose type of sugar instead of the deoxyribose . The bases are the same except that uracil is present in the place of aine.

24.2—2 Reproduction of DNA

Just before cell division, the replication of DNA molecules takes place. The

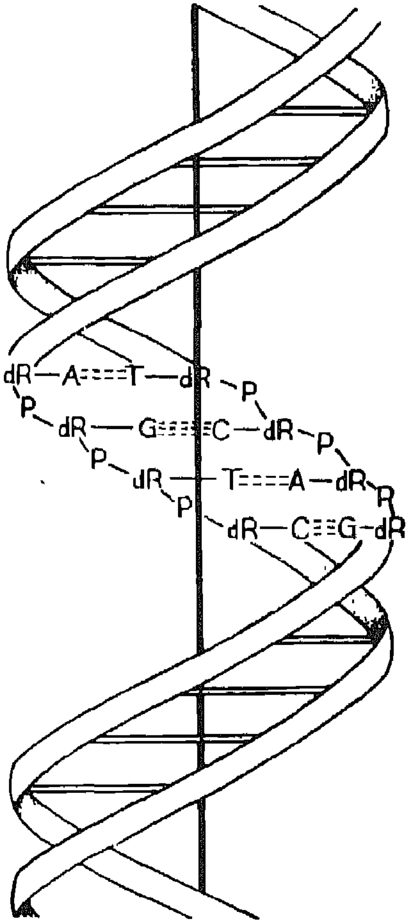


Fig 24 3 Structure of the DNA molecule. Note that adenine binds with thymine and guanine with cytosine,

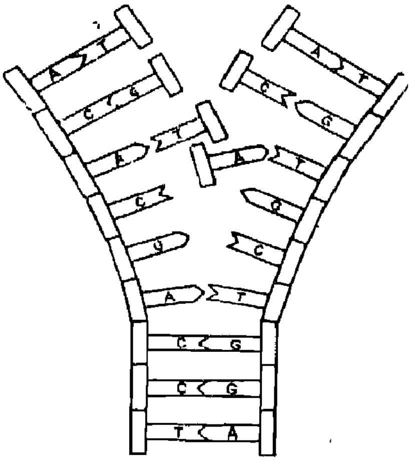


Fig. 24 4 Duplication of DNA. The two original strands uncoil and each of them acts as the template for a new strand.

two strands of the helix separate and each strand builds up its complementary partner (Fig. 24.4). In this manner, the two DNA molecules are synthesised which go along with respective chromosomes to the daughter nuclei.

24.3 Evolution of life on earth

When you visit a zoo or when you look at the plants and animals around you, you certainly wonder as to how so many varied forms have originated ? You are already aware of the extent of diversity (Fig. 2.5) of life forms. How did all these species originate ?

When the living forms first appeared on the surface of our planet they were very simple. As the years rolled by life became more and more complex ill ultimately it culminated in the various forms of today. This is the idea of *rganic evolution.* All living forms existing today have evolved from simpler orms which existed on the earth long back. In other words, each species, spite of its stability, is in a state of flux within certain limits and when it ranscends these limits it is modified into a new species.

According to the doctrine of organic evolution all the animals and plants hich are existing today have descended from simpler pre-existing forms. ence evolution is defined as *descent with modification.*

A host of evidences that evolution has actually taken place have now been cumulated. A short account of these evidences is given below.

.2—1 Evidences of evolution

IDENCES FROM PALAEONTOLOGY

The study of past life with the help of fossils is known as *Palaeontology.* e geological record is written in the language of fossils which may be the tual remains of the animals buried underground or may be their casts, moulds impressions. The primary and direct evidence in favour of evolution is nished by fossils. The fossils are found in the sedimentary rocks, the lowest ata of which provide fossils of lower animals. In the successive upper strata sedimentary rocks higher and higher forms of plant and animal fossils are tained. From these fossils we can learn not only something about the living ms but also about the geological conditions of that period. It must be membered that fossilisation occurs only under ideal conditions. There are two very important conditions for the formation of a fossil. The living organisms should have some hard structure, e.g. bones and teeth in the case of vertebrates, shell in molluscs, exoskeleton in arthropods, etc. Secondly, it should be preserved in some protecting medium, e g. oil-soaked ground, volcanic ash, ice, amber, sand, etc.

Various methods are now known whereby more or less the exact age of the fossils and the sedimentary rocks can be determined and the entire geological period can then be divided into several *eras*.

Each era is subdivided into *periods* and in turn periods are further divided into several *epochs*.

Although the fossil records are often incomplete, nearly complete sequences of fossils have been discovered in the case of horse, camel, elephant and man. However, the fossils of family Equidae are nearly complete and are the most reliable record of evolution. The dawn horse—five-toed *Eohippus* of North America and Europe—gave rise to *Mesohippus* which in turn developed into serveral lines of evolution. Finally the modern one-toed *Equus* evolved from *Pliohippus* (Fig. 24.5). However, many fossils were discovered which have no resemblance to any of the present day forms and several others exhibited mixed characters of two living groups. The latter type are known as connecting links between two groups. Thus from the study of fossils you may conclude the following :

1. The surface of the earth has changed in course of time and so also have its living inhabitants.
2. Living forms with simple organisation appeared earlier than the complex forms.
3. Several forms bearing intermediate characters indicate transition from an earlier simple to a later complex form.
4. Some living forms which were once present failed to survive and thus became extinct.

EVIDENCES FROM COMPARATIVE ANATOMY

Various plants and animals carry out certain functions for their existence. These life processes have certain common features and at the same time exhibit certain differences. For example, all the chordates like fish, toad, lizard, pigeon and guineapig possess the heart for pumping blood and the brain for controlling different activities. If you examine the hearts and the brains of some of these animals (Fig. 24.6), you will find that the organs are simpler in

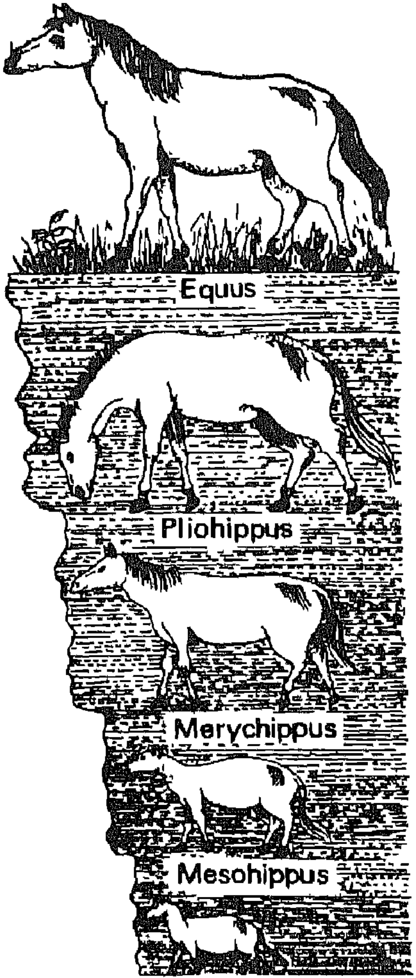


Fig 24 5 Evolution of horse from *Eohippus* to *Equus*

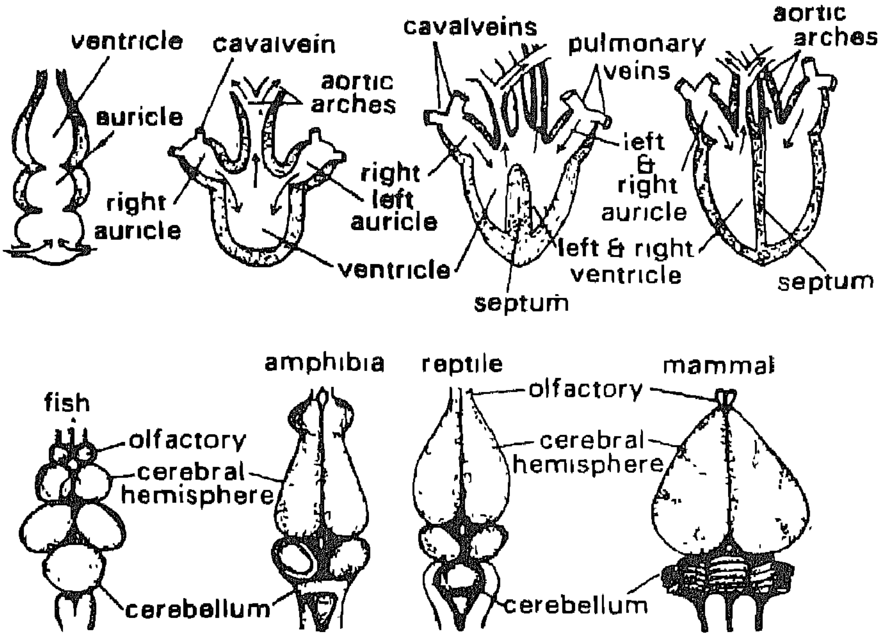


Fig. 24 6 A. Structure of the heart in different vertebrates
B. Structure of the brain in different vertebrates

fishes which gradually become more complex in the toad, lizard and guineapig. This is true of all other organs. Fossils show that fishes appeared first and were followed by the amphibians, reptiles and mammals. The study of comparative anatomy, when combined with fossil evidences, provides a strong support to the idea of organic evolution; animals which originated earlier had a simpler organisation and were followed by complex forms.

Homologous Organs. Comparative anatomy provides a number of other evidences. For example, Fig 24 7 shows the forelimbs of different vertebrates. If you look carefully, you will find that there exists a similarity in the basic structural plan but their functions are different. In all of them, the same skeletal elements are present. In all these animals, the forelimbs develop from the same area and follow the same pattern of development. Such organs, having similar origin, may be functionally different. They are called *homologous*

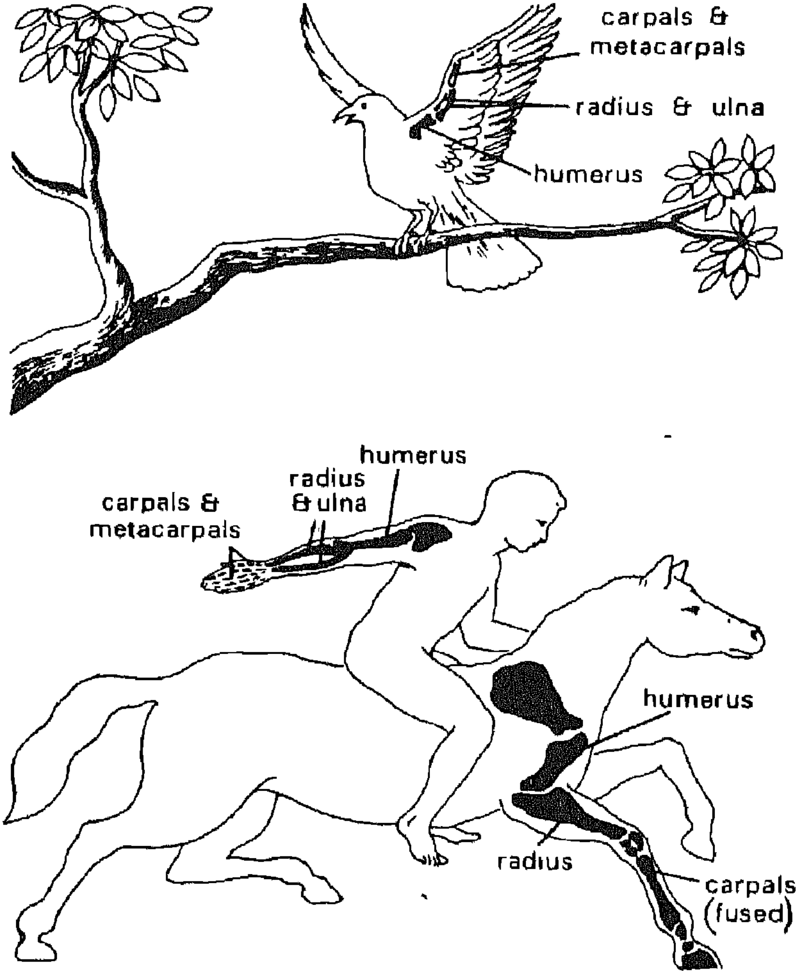


Fig. 24.7 Forelimbs of different vertebrates

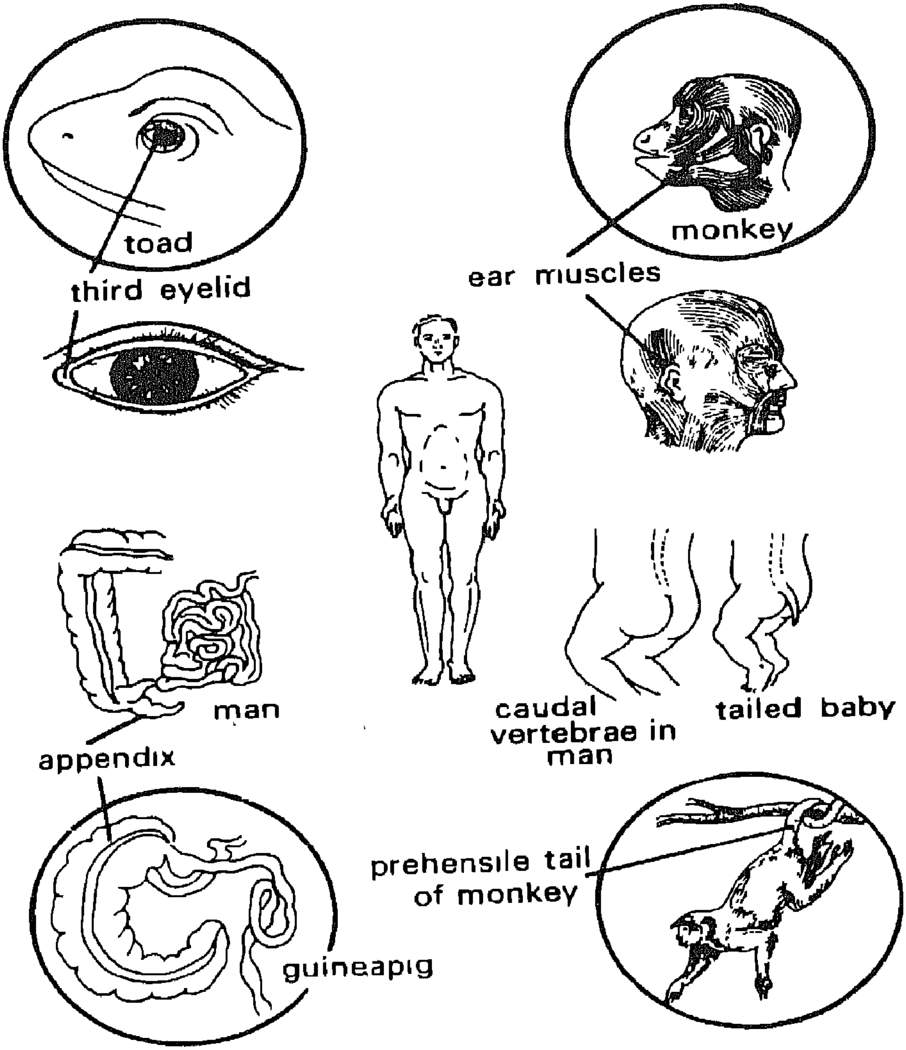


Fig. 24.8 A few organs which are functional in other animals (inside circles) but are vestigeal in man.

organs. The homologous organs speak of a common ancestry of all these diverse forms. Manifestations of this basic pattern have changed in each form according to its specific functions.

Vestigeal organs. In your body there are certain functionless structures (Fig. 24.8) called vestigeal organs. Those organs are fully functional in other animals. The vestigeal organs are also present in other animals. What is their significance ? Their presence supports the view of organic evolution. It indicates that the organisms with both the vestigeal and functional organs must have evolved from a common ancestor.

Evidences from classification. While studying variation you have noticed that all cats, though dissimilar, have certain common features by which they may be separated from tigers and dogs. As regards their characteristic features, cats are closer to tigers, than to dogs. Thus, the cats are grouped with the tigers, and the dogs are grouped with the foxes. Cats, tigers, dogs and foxes are closely related. For this reason they are kept in one bigger group, while man and monkey are kept in another.

All of the above animals, because of their certain common features, are placed in a wider group which is different from that of birds, reptiles, amphibians and fishes. Such grouping on the basis of actual kinship of organisms forms the basis of *Biological Classification.* It provides an important evidence for the idea of evolution, that is, origin from a common ancestor.

EVIDENCES FROM COMPARATIVE EMBRYOLOGY

Except for a few specialised types of reproduction, a multi-cellular animal originates as a zygote or fertilised egg. The zygote of each species has the distinctive ability to produce an individual of that species. But there are many features of embryonic development common to members of any animal group. Therefore, we might anticipate that similar final results would usually be achieed by similar developmental processes. Certain embryonic similarities are hown in Fig. 24.9 which represents several stages in the development of fish, alamander, turtle, chick, rabbit and man. Each sequence begins with a single rtilised egg (zygote). To facilitate comparison, the structures of different ages of different animals are drawn about the same size, although they vary their actual size.

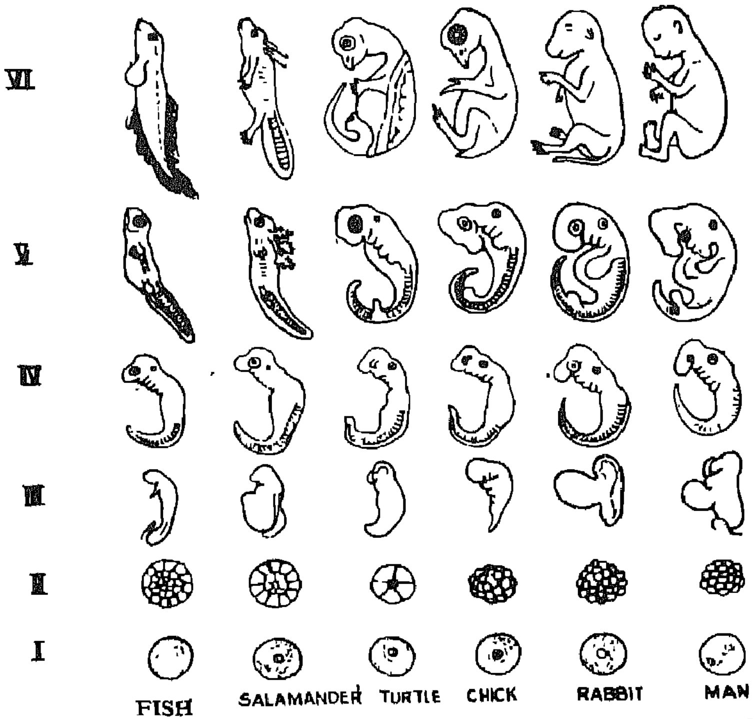


Fig. 24.9 Developmental stages of different vertebrates from fish to man. Note the similarities of the embryonic stages of various animals

EVIDENCES FROM BIOCHEMISTRY AND METABOLISM

The modern chemical study of animal has also provided strong support to the idea of organic evolution. Animals of different species may differ morphologically in their structure, but they are almost identical in their chemical make-up.

Carbohydrates, fats and proteins are used by the body as fuel to provide energy for all phases of metabolism. The mechanism of energy production and storage is nearly the same throughout the animal kingdom. The universal energy carrier, ATP (adenosine triphosphate), is synthesised by the process of phosphorylation in the cell with the help of mitochondria.

These fundamental similarities can only be explained by the idea of organic evolution, i. e. all these animals have evolved from a common ancestor.

EVIDENCES FROM CYTOLOGY

The fundamental structure of a cell is similar throughout the animal kingdom. Why this is so ?

Not only this, but the processes by which cell divides (mitosis and meiosis) are also same throughout the animal kingdom. The only explanation is that all the animals had a common origin.

EVIDENCES FROM GENETICS

Genetical studies give strong support to the theory of organic evolution. Long ago, Darwin noticed the variations among the individuals of the same species. He was, however, unable to explain the source of variations but now the science of genetics has explained the phenomenon on the basis of mutation and recombination of genes. This new technique has been successfully utilised in hybridization and domestication of animals and plants Geneticists have roduced, by proper selection and controlled mating, a good number of hybrids. or example, the mule is the offspring from a cross between an ass (*Equus sinus*) and a mare (*Equus cabalus*). This animal is very strong and hardy but terile.

Some new varieties of chicken, dog, cattle and horse have been evolved rtificially which breed true so long as interbreeding with other varieties is revented.

.3—2 *Theory of organic evolution*

You have already learnt that the idea of organic evolution is quite old. merous theories have been put forward to explain organic evolution. Of se, the theory put forward by Darwin was based on a variety of evidences. arles Darwin for the first time gave proper explanations of organic evolution the basis of a large number of evidences. The works of Charles Darwin only established the idea of organic evolution but also steered the human ughts into a different direction.

Fig. 24.10 Charles Robert Darwin

Fig. 24.11 Alfred Russel Wallace, who independently reached the same conclusion as that of Darwin

DARWINISM

Charles Darwin (1809-1882), the great evolutionist of all times (Fig. 24.10) went on voyage on the ship H.M.S. *Beagle* (1831-36) and collected large amount of data which convinced him that evolution had occurred. The evidence consisted of (1) succession of fossils to be found in sedimentary rocks, (2) replacement of living forms of closely related species as the nature of habitat changed, and (3) the distribution of animals (finches) and plants in the Galapagos islands. Soon after his return Darwin read the work of Malthus on the principles of population and was greatly impressed by the alarming potential speed of multiplication of the human race. Another evolutionist Alfred Russel Wallace (Fig. 24 11), a contemporary of Darwin, also came to the same conclusion independently. In substance the theory of Darwin can be summarised as follow :

1. He accepted from Malthus the fact that the reproductive powers of animals are much greater than necessary to maintain their numbers. Only if a very large population of the offspring are destroyed will the members remain constant as they normally do.
2. If a large number of individuals are being destroyed there must be a struggle for existence both between the members of the species and also between species, i.e. the struggle for existence will be both intra- and inter-specific.
3. Animals vary and so he assumed that their variations are inherited.
4. In the struggle for existence, the favourable variations will survive and the unfavourable ones will be exterminated. The favourable variations will accumulate, and this natural selection will lead to gradual change in the characters of species towards better adaptation. This gradual change when it has proceeded enough will result in the origin of new species.

Darwin made two outstanding contributions to evolutionary thought. The first of these was his establishment of evolution as a process. He was able to present enough convincing data that evolution had indeed occurred. His second contribution was his identification of natural selection as an important factor in adaptation and the origin of species.

The period between 1859 and 1900 was a time of rapid development in biology. Mendel's work was published in 1866, chromosomes and their behaviour in mitosis and meiosis were discovered between 1866 and 1885, and rapid progress was evident in virtually every area of biology. In 1900, Mendel's work was rediscovered and fundamental principles of genetics were clarified. With the enormous amount of knowledge gained it became obvious that many of the views expressed by Darwin were unfounded. For instance, his belief in blending inheritance (characteristics of the parents merged together in the descendants, thus losing their original identity) has been shown to be wrong; his acceptance of Lamarckian inheritance as playing some part in evolution has ot been confirmed.

The Darwinian theory of evolution in the form accepted by the biologists f 1900 had more than one weak side. Subsequent work in later years clarified and strengthened his view-points and brought about universal acceptance of the theory of natural selection as a guiding force in evolution.

The development of evolutionary concept in the post-Darwinian period of the early 20th century with the central theme of natural selection has been known as Neo-Darwinism.

EXERCISES

1. What is the cause of differences between two species ?
2. How are the hereditary variations produced ?
3. Why did Mendel select the pea plant for his experiments ?
4. What were the methods of Mendel's experiments ?
5. Explain the following terms ·
   (i) Allele, (ii) Genotype; (iii) Phenotype; (iv) Heterozygote, and (v) Homozygote.
6. What is the significance of Mendel's theory ?
7. How does DNA differ from RNA ?
8. What is the composition of a nucleic acid molecule ?
9. Describe the chemical nature of DNA, and draw its structure
10. How does a DNA molecule duplicate ?
11. Name the areas of human knowledge from which the evidences for organic evolution were collected.
12. What do you deduce from the fossil evidences ?
13. What do you deduce from the evidences of comparative anatomy ?
14. What are homologous organs ? What is their significance ? Name a few vestigeal organs in the human body
15. Embryos of all vertebrates look alike in their early stages of development. What does it signify ?
16. Discuss Darwin's theory of Natural Selection.

Chapter 25

Electricity

25.1 Force between electric charges

We know that there are two types of electric charges, viz., positive and negative Two like charges repel and two unlike charges attract each other What is the law governing their interaction ? We may investigate it with the help of an experimental arrangement shown in Fig. 25.1

A ball A is attached to one end of an insulating rod pivotted as shown. A weak spring tied at the other end balances the weight of the ball. A pointer is attached as shown and the position of the pointer can be read on a vertical scale. The ball A and an identical ball B may be given the same kind of charge (say+ve) by means of an electrophorus As the balls A and B are brought close to each other (not touching), there will be a repulsion and the pointer will show a deflection on the scale The spring acts like a spring balance and, thus, the deflection is an indicator of the force

Let us investigate the relation between the distance r of the centres of A and B and the force as measured by the deflection d of the pointer. We shall see that if we plot a graph between $1/r^2$ and d, we get a straight line as shown in Fig. 25.2.

In other words, the force F between the two charged bodies varies inversely as the square of the distance between them, i.e.,

$$F \alpha \frac{1}{r^2}$$

Apart from this, one can also investigate how the force depends on the harges on the bodies A and B. Coulomb established the law that the *force etween two charges is directly proportional to the product of the two charges nd inversely proportional to the square of the distance between them.*

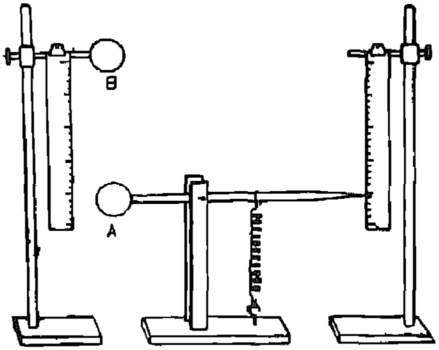


Fig. 25.1 An experimental arrangement to study Coulomb's law

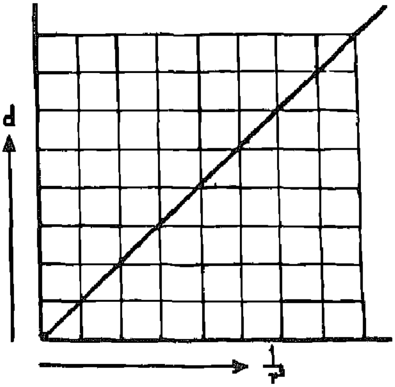


Fig. 25.2 Plot of $\frac{1}{r^2}$ against d

Mathematically, Coulomb's law states :

$F \propto q_1 q_2$ (r constant)

$\propto \frac{1}{r^2}$ (q_1 and q_2 constant)

$$\text{or } F = K\frac{q_1 q_2}{r^2} \qquad \ldots (25-1)$$

where K is a constant of proportionality.

In the S I. units, the charge is measured in coulomb. The coulomb turns out to be a convenient practical unit and is simply related to other common electrical units, such as ampere, volt, watt and ohm. The coulomb is in fact a very large amount of charge in the sense that one coulomb is equal to the charge of 6.2×10^{18} electrons

It can be shown that two charges of 1 coulomb each placed at a distance of 1 metre experience a force of 9×10^9 newton.

From the equation (25—1), it can be seen that by putting

$q_1 = q_2 = 1C$; $r = 1$ m

the value of K is

$$K = 9 \times 10^9 \frac{Nm^2}{C^2}$$

Actually, a force of 9×10^9 newton is a very large force, the equivalent of approximately the weight of a thousand million kilogram. Normally, when we charge bodies, such as by rubbing a comb against our hair, the charge would only be about a millionth of a coulomb. Thus, the forces between such charged bodies would be quite small.

25.2 Electric intensity

Suppose, we have a charge Q at a point O (Fig. 25.3). From Coulomb's law, we know that the force experienced by a unit positive charge placed at A at a distance r from Q is

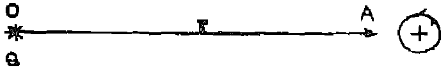


Fig. 25.3 A unit positive charge in the neighbourhood of a charge Q

$$F\ (\text{at A}) = K\ \frac{Q}{r^2} \qquad \ldots (25-2)$$

This quantity is called the *electric intensity* at A due to the charge Q and is represented by E. Once we know the electric intensity at any point A, we can easily find the force acting on any charge q placed at that point. We have

$$F = qE \qquad \ldots (25-3)$$

The direction of the electric intensity E is the same as that of the force acting on the positive charge.

From the equation (25—3), we see that the unit of electric intensity is newton per coulomb, i.e., $\frac{N}{C}$.

25.3 Electrostatic potential energy

We have seen in chapter 5 that when we lift the mass m from the ground to a height h, we say that the system has acquired potential energy mgh by virtue of its configuration The zero level of the potential energy here is the configuration when the mass is at the ground level.

It is obvious that when two similar charges are brought closer, work has to be done against the force of repulsion between the charges. This work results in the increase in the potential energy due to the change in the configuration of the system. By convention, the zero level of the electrical potential energy is the configuration when the two charges are very far apart (separated by an infinite distance).

It can be shown that the potential energy of two charges q_1 and q_2 separated by a distance r is given by

$$\phi = \frac{Kq_1\,q_2}{r} \qquad \cdots (25-4)$$

25.4 Potential due to a charge

Suppose, we have a charge + Q at a point O and we bring a unit positive charge to A from infinity. The work done will be given by $K\,\frac{Q\times 1}{r}$. This work $K\,\frac{Q}{r}$ is known as the electrostatic potential at the point A (located at a distance r from Q) due to the charge Q. Thus, a point nearer to Q will be at a higher potential than a farther point.

Supposing, the charge at A is free to move, it is clear that it will move away from the charge Q in the direction of the arrow (Fig. 25.4).

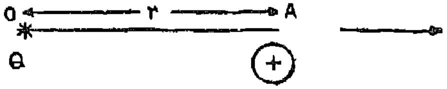


Fig. 25.4 A unit positive charge being brought from infinity to a point

In other words, the charge will flow—just as water flows—from a higher to a lower potential. This makes the potential a very useful concept, since it determines the direction of the flow of a positive charge. A little thought will show that a negative charge will flow from a lower to a higher potential.

25.5 Electric current

Suppose, we have two metallic spheres at different potentials. In general, the charges will not be able to move freely from one sphere to the other, inspite of the potential difference. This is because the charges will be unable to leave the surface of the spheres. However, if they are connected by a conducting wire, flow of the charges takes place. This flow continues until there is no longer a potential difference. Such a flow of the charges constitutes an *electric current*.

It is possible to maintain the flow of the charges, i e , the current, if we can maintain a potential difference between the ends of the wire. The simplest way is to connect it across a battery (Fig. 25.5). Such an arrangement resulting in the flow of the current is called *electrical circuit* The magnitude of the current I is the charge flowing in the circuit per second, i.e ,

$$I=\frac{Q}{t}$$

where Q is the charge in coulomb flowing in *t* second. The unit of current is the ampere,

$$1\ A=\frac{1\ C}{s}$$

The charges that flow in an electrical circuit are usually electrons. It is to be noted that electrons flow from a lower to a higher potential, however, by convention, one says that the current flows in the direction opposite to that of the electrons.

If the current-flow in a circuit is always in the same direction, it is called *direct current* or D. C. Sometimes, it is so arranged that the electrons flow alternately backwards and forwards. In this case, the current is called *alternating current* or A.C.

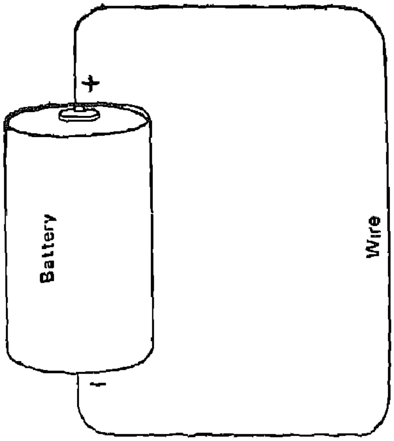


Fig 25 5 An electrical circuit

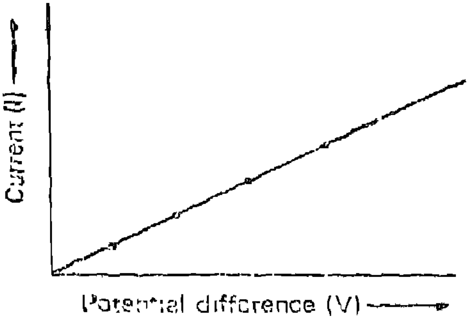


Fig 25.6 The variation of a current with a potential difference

25.6 Ohm's law : Resistance

An electric current flowing through a conductor depends upon the potential difference across its ends. When the potential difference across the conductor is changed, the current in the circuit will also change The potential difference across the ends of a conductor is increased by connecting the conductor with more cells and each time the current in the circuit is noted. If the potential difference V is plotted along X-axis and the current I along Y-axis, a straight line graph is obtained (Fig. 25.6). This shows that the ratio of V and I is a constant This constant is called the *resistance* of the conductor. This important relation between the current and the potential difference in a conductor was noticed by a German school teacher George Simon Ohm in 1826. The law which governs this relation is known as *Ohm's law.*

Ohm's law states : *At constant temperature, the current flowing through a conductor is proportional to the potential difference across its ends.* When a battery is connected with a conductor, the chemical energy of the battery produces an electric field at the two ends of the conductor, one terminal becomes positive and the other terminal, negative. Work is done in moving the charge from one terminal of the battery to the other along an external path. When the charge moves through a material, it encounters collisions with the particles of the material and loses a part of its energy. The loss of energy appears as heat in the conductor. This gives rise to the resistance of the material of the conductor. Resistance varies from material to material.

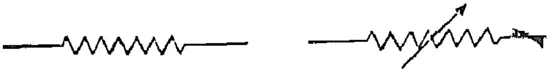
The unit of resistance is called *ohm.* It is expressed by the Greek alphabet Ω. If the potential difference across the ends of a conductor is 1 volt and the current flowing through the conductor is 1 ampere, then the resistance of the conductor is 1 ohm.

$$1\ \Omega = \frac{1\ \text{V}}{1\ \text{A}} \qquad \text{.. (25—5)}$$

The resistance in a circuit is expressed by the symbol shown in Fig. 25.7 (a) and a variable resistance in a circuit is expressed by the symbol shown in Fig. 25.7 (b).

25.7 Resistances in series and parallel

To get a desired current in a circuit, more than one resistance are frequently used. If a single resistance replaces the combined resistances in such a manner that the current in the circuit remains unaltered, then the single resistance is called the *equivalent resistance*. Resistances are combined in two main ways : (a) series combination, and (b) parallel combination.



(a) (b)

Fig 25 7 Symbols for resistance

(a) Series combination

In the series combination, the resistances are connected as shown in Fig. 25.8, so that the same current flows through them. The current I flows through the resistances R_1, R_2 and R_3 The potential difference between each of the conductors will be

$V_A - V_B = IR_1$; $V_B - V_C = IR_2$, $V_C - V_D = IR_3$

If the equivalent resistance is R, then

$V_A - V_D = IR$

Therefore, $IR = IR_1 + IR_2 + IR_3$

or $$R = R_1 + R_2 + R_3 \qquad \ldots (25-6)$$

(b) Parallel combination

In this combination, one end of each resistance is connected at one point, and the other ends at some other point (Fig. 25.9).

The three resistances are terminated at the points A and B. The current I is branched at the point A into I_1, I_2 and I_3. These branched currents recombine at the point B.

$\therefore I = I_1 + I_2 + I_3$

Now, $I_1 = \frac{V_A - V_B}{R_1}$; $I_2 = \frac{V_A - V_B}{R_2}$; $I_3 = \frac{V_A - V_B}{R_3}$

If R is the equivalent resistance, then

$$I = \frac{V_A - V_B}{R}$$

$$\therefore \frac{V_A - V_B}{R} = \frac{V_A - V_B}{R_1} + \frac{V_A - V_B}{R_2} + \frac{V_A - V_B}{R_3}$$

or $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \ldots (25-7)$$

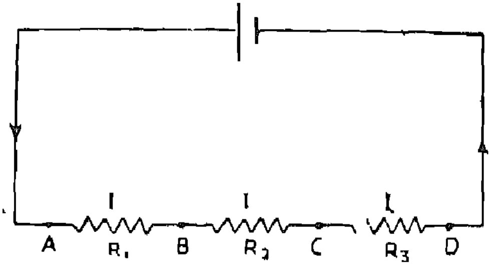


Fig 25.8 Series combination of resistances

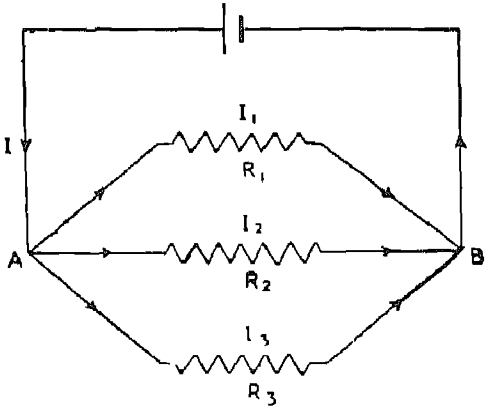


Fig. 25.9 Parallel combination of resistances

25 8 Work and power in electric circuits

Work is done in a conductor when electrons are forced to move. When one coulomb of electricity moves against a potential difference of one volt, the work done is one joule Since power is the rate of doing work, the power consumed in an electrical circuit indicates the rate at which electrical energy is consumed. The higher the power, the higher the rate of consumption of electricity. We have seen 15W, 40W, 100W, etc, engraved on electrical bulbs. W stands for the unit of power *watt* A 100W bulb consumes energy at a faster rate than a 40W bulb The rate of doing one joule of work in one second is called one watt. So, by definition 1 watt = 1 volt × 1 ampere. A watt is a small unit. So a large unit of power called *kilowatt* is used. It is expressed as kW.

Domestic and industrial consumption of electricity is recorded by another unit known as *killowatt-hour*. It is expressed as kWh. If work is done at the rate of 1kW in one second, then the total energy spent in one hour is called one kilowatt-hour. So, if a radio-set of 60W runs for 50 hours, then the energy spent is 50 × 60 watt-hour = 3 kWh. If the cost of 1 kWh is 40 paise, then the total cost will be Rs. 1.20.

EXERCISES

1. If the distance between two charges is doubled, the force between them would become
   (A) double
   (B) half
   (C) one-fourth
   (D) four times
2. In an electric field, the work done in moving a unit positive charge between two points is the measure of the
   (A) intensity of the electric field
   (B) potential difference
   (C) current
   (D) resistance
3. Distinguish between the potential and the potential difference.
4. How would you justify that the total charge of the bodies do not change when a body is charged by rubbing it against another body ?
5. Describe briefly the method for determining the resistance of a coil by using a voltmeter and an ammeter. Draw a diagram of the circuit used. Also, mention the major precautions to be taken during the experiment.
6. Plot a graph between V and I from the following data and interpret it·

I (in ampere)	0.555	0.110	0.170	0.230	0.295	0.325	0.590
V (in volt)	1.30	2.60	4.00	5.45	6.95	7.70	9.20

7. (a) Derive the formulae for the effective resistance in the case of resistances connected
      (i) in series, and
      (ii) in parallel
   (b) How can three resistances of 2, 3 and 6 ohms be connected to give a total resistance of 1 ohm ?
8. Three 4.5Ω resistances are connected in series with a dry cell of 1.5V. What is the current ? If the resistances are connected in parallel in the same circuit, what will be the current ?
9. A 60W lamp is connected to 220 V mains. What is the current in the coil of the lamp ? What is the resistance of the coil ?

Chapter 26

Magnetism

26.1 Introduction

In the second century, the Greeks detected peculiar properties of loadstone, an impure oxide of iron. It could detect iron and point north-south when suspended freely. As the legend goes, a Greek shepherd detected this stone in Magnesia in Asia minor. These stones were named magnets from the word Magnesia and the peculiar properties were termed as *Magnetism*.

For a long time magnetism was associated only with a loadstone and other magnets. The modern study of magnetism began with the discovery by Oersted that a magnetic needle in the neighbourhood of a current-carrying wire undergoes deflection. This experiment showed that magnetism is associated with an electric current, i.e., with moving charges.

Oersted's discovery showed that an electric current exerts force on a magnet. We may recall that, according to Newton's third law of motion, the magnet, therefore, should also exert equal and opposite force on the current. We have learnt in earlier classes that we can associate a magnetic field with a magnet. One can say, therefore, that a magnetic field exerts a force on currents.

26.2 Magnetic field due to a current

Consider, now, a wire carrying a current I placed between the pole pieces of a large magnet as shown in Fig 26.1. The wire is perpendicular to the magnetic lines of force. Experiments show that the force experienced by the wire is proportional to the current it carries and also the length l of the wire that is in the magnetic field, i.e .

$$F \propto I \times l \qquad (26-1)$$

We define the magnetic field B as

$$B = F/I \times l \qquad \cdots (26\text{—}2)$$

In the S.I. units, F is measured in newton, I in ampere and l in metre. Thus, B is measured in newton per ampere-metre This unit, newton per ampere-metre, is called *tesla* (T).

Experiments also show that the forces on the current-carrying wire is perpendicular to the direction of the current as well as to the direction of the magnetic field as shown in the diagram. (We may use Fleming's left-hand rule as illustrated in Fig. 26.2).

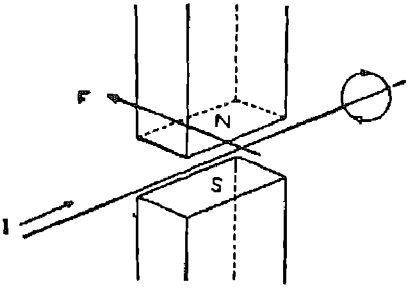


Fig 26.1 A current-carrying conductor lying perpendicular to a uniform magnetic field

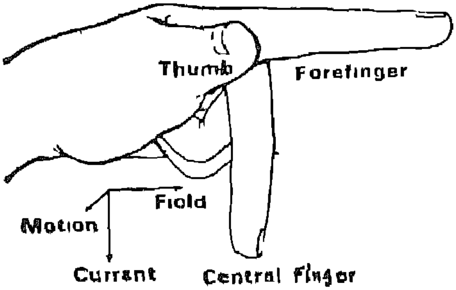


Fig 26.2 Fleming's left-hand rule

Earlier, we have seen that an electric current is just a flow of charges. Thus, moving charges in free space, like currents in a wire. also experience force in a magnetic field. The direction of the force on a moving positive charge is exactly the same as that of a current.

One of the exciting discoveries related to the deflection of charged particles by a magnetic field was the so-called Van Allen radiation belt. This discovery was made possible by using unmanned satellites. This belt is a vast zone of trapped charges encircling the earth above the equatorial regions. The charged particles are derived mostly from the sun and are trapped by the magnetic field of the earth.

The effect of a magnetic field on moving charges has been used in television, oscilloscopes and also in machines which are used to accelerate charged particles used for scientific research. One such machine, called a variable energy cyclotron, will soon be in operation in Calcutta.

26.3 Interaction of two current-carrying wires

Since currents are associated with magnetic effects, it should not surprise us to learn that two current-carring wires will experience force. Indeed, Ampere tried this as soon as he learnt about Oersted's discovery.

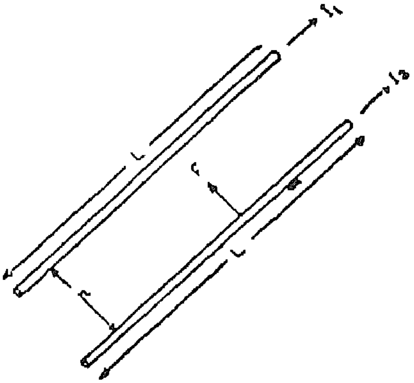


Fig. 26.3 Force between two current-carrying conductors

It is found that two long parrallel wires carrying currents in the same direction attract each other; if the currents are in the opposite directions, they repel. It turns out that the force between the wires (Fig. 26.3) is given by the following relation:

$$F = \frac{\mu_0}{2\pi} \frac{I_1 \times I_2 \times L}{r} \qquad (26—3)$$

Here I_1 and I_2 are the currents (in ampere) in the wires, L is the length (in metre) of each of the wires, and r is the distance (in metre) between them. The force is in newtons.

The constant μ_0 is found to have the value $4\pi \times 10^{-7} N/A^2$.

The force between the currents in typical practical situations is extremely small. For example, $I_1 = I_2 = 2A$, $L = 1$ m and $r = 0.01$ m gives a force of 8×10^{-5} N, or about 8 milligram weight. Thus, we should not be surprised that ordinary wires used in electrical appliances experience too small force for us to detect.

From the equation (26—3), we can also calculate the magnetic field due to the first wire at a distance *r*, namely, at the second wire. We have

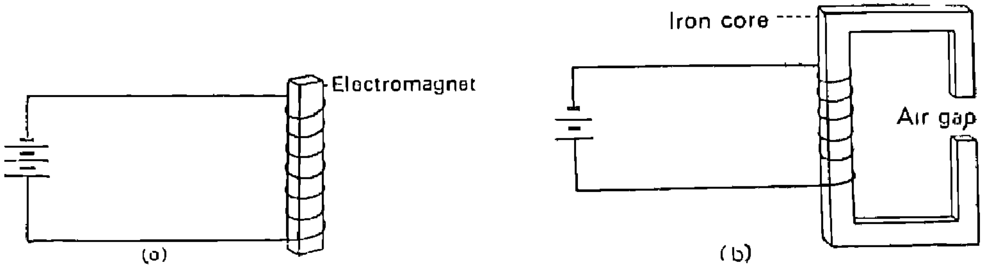
$$B = \frac{F}{I^2 L} = \frac{\mu_0 I_1}{2\pi r} \qquad (26\text{—}4)$$

Thus, the field due to a straight wire varies inversely as the distance from it and is directly proportional to the current in it.

The direction of the magnatic field due to a straight wire carrying the current depends on the right-handed screw rule as discussed earlier.

26.4 Electromagnet

Often, in practical applications and in scientific work, it is necessary to produce large magnetic fields, the field due to a straight wire carrying a few amperes current is not appreciable. We can make it bigger by winding the wire in the form of a coil Then, the magnetic field of one turn of wire adds to the magnetic field from the next turn, and so on. If we make a coil with a large numbers of turns and put a piece of iron inside, we can get a much larger magnetic field. Such a device is called *electromagnet* (Fig. 26.4).



(a) (b)

Fig. 26.4 Electromagnet

One of the common shapes of an electromagnet in Fig 26.4b is that of a C-shaped electromagnet. The magnetic field in the air gap between the tips will be much larger than outside.

We have seen that electrical and magnetic devices experience mechanical forces. One can use electro-magnetism to produce mechanical energy and also convert mechanical energy into electrical energy.

26.5 Dynamo

A dynamo is a machine by which mechanical energy is converted into electrical energy. In a dynamo, a coil of wire is made to rotate in a magnetic field. The axis about which the coil rotates is perpendicular to the lines of force of the magnet As the coil rotates, the number of lines of force cut by the coil changes and an electromotive force is induced between the two ends of the coil. ABCD is a coil of wire which is made to rotate about a horizontal axis XY in a magnetic field (Fig 26 5) N and S are the north and south poles of the magnet The lines of force are perpendicular to the axis XY. The coil is wound on a soft iron cylinder called the *armature*. Let us suppose that the coil rapidly rotates in a clockwise direction. According to the right-hand rule (similar to Fleming's left-hand using rule the right hand), the direction of the current will be along ABCD. The number of lines of force cut by the coil is minimum when the plane of the coil ABCD is horizontal and maximum when it is vertical So, the induced current is minimum when the plane of the coil is horizontal and maximum when it is vertical. After the half rotation, CD occupies the position previously occupied by AB. In this position, CD is horizontal and the induced current is minimum. Due to the rotation, CD rises and the current flows in the opposite direction along DCBA The current again becomes maximum when the plane of the coil is vertical. But this time the direction of the current is negative.

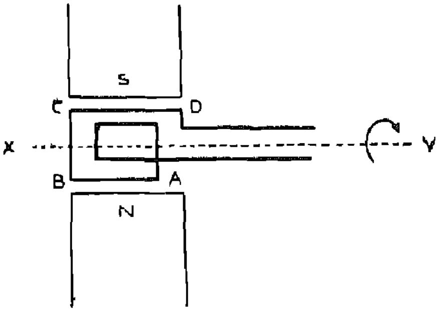


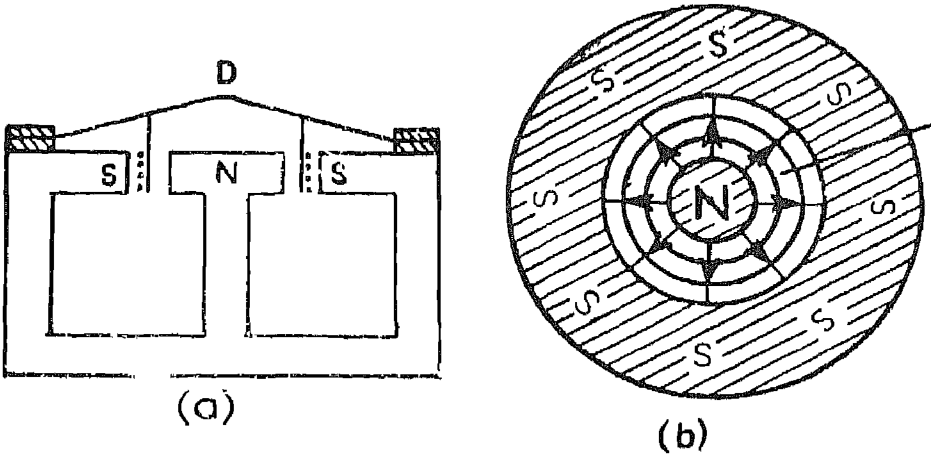
Fig. 26.5 The principles of a dynamo

So for a complete rotation, the value of the current starts from zero, becomes maximum and then starts diminishing. The current again becomes zero and then becomes maximum in the opposite direction after which the current begins to decrease The change of the current in one complete rotation is called *cycle*. The number of cycles per second is called *frequency* Since the magnitude of the current varies in a cycle, this current is called *alternating current*.

The terminals of the coil ABCD are connected to two rings, which are lightly attached to two carbon brushes from where the current lines are drawn for use.

26 6 Principle of a microphone

In a microphone, sound energy is converted into electrical energy. This electrical energy is transmitted after amplification to the required distances for re-conversion into sound energy by loud-speakers. Different types of microphones have been manufactured for different uses. Mainly three types of microphones are in use; namely, (a) the moving coil microphone; (b) the carbon microphone; and (c) the crystal microphone. The moving coil microphone is widely used in broadcasting and public address system.



(a)

(b)

Fig 26.6 The cross-sectional view of a microphone

The moving coil microphone consists of a specially designed magnet made of an alloy of cobalt and steel. The north pole of the magnet lies at the centre round which lies the south pole in the form of a ring (Fig 26 6). In front of the magnet, there is a diaphragm D, the central part of which is slightly raised and its edge is firmly fixed to an outer casing. A light conical structure made of aluminium is connected to the diaphragm. An insulated coil C is wound on this aluminium structure. The coil with this metal structure is kept in the cavity between the two pole pieces.

When sound waves fall on the diaphragm, it vibrates in the same vibrating pattern and the coil vibrates back and forth in the cavity. An *emf* is induced in the coil as it vibrates in the strong magnetic field and the magnitude of the *emf* depends upon the nature of the incident sound wave. Thus, variable electrical energy is obtained which is transmitted to the required distances and then fed into an instrument called loud-speaker for re-conversion into sound waves.

26 7 Telephone

In a telephone, sound energy is converted into electrical energy in the transmitting part, which flows along the wire to the receiving part of another unit where it is re-converted into sound energy. Each telephone has two parts

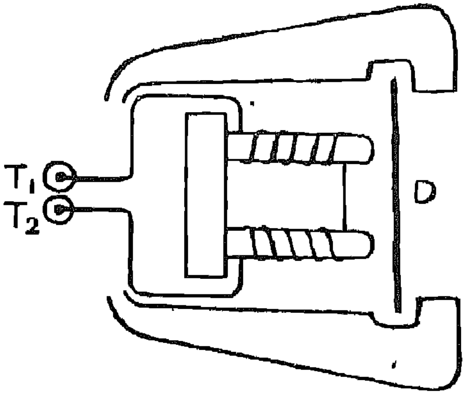


Fig. 26.7 The earpiece of a telephone

in the same unit, the transmitting part and the receiving part. The transmitter of one is connected with the receiver of the other. The receiver is also called the *earpiece*.

The receiver or the earpiece of a telephone has a U-shaped horse-shoe electromagnet (Fig. 26.7). Each pole of the electromagnet has a coil wound on it and the two coils are connected in series. The free ends of the coils are connected with the connecting wires to two terminal screws T_1 and T_2 A thin diaphragm D is attached in front of the magnet. The diaphragm vibrates when the electrical energy in the coil of the electromagnet changes. The receiver can also be used as a transmitter. When sound waves fall on the diaphragm, it vibrates with the same frequency and displacement The diaphragm becomes an induced magnet and induces an *emf* in the coil when it vibrates. This induced electrical energy flows along the wire which causes the diaphragm of the receiver to vibrate. The vibration of the diaphragm of the receiver produces sound. Generally, the carbon microphone is used as a transmitter about which we will learn in higher classes.

26.8 The earth's magnetism

A freely suspended magnet points north and south. This behaviour of a magnet indicates that the earth is a huge magnet with its north pole lying in the geographical south and the south pole lying in the geographical north In the sixteenth century, William Gilbert, physician to the Queen Elizabeth I pointed out this magnetic behaviour of the earth. A freely suspended magnetic needle makes an angle of about 18° with the axis of the earth This is because the angle between the magnetic axis and the geographical axis is about 18° (Fig. 26.8).

The earth's magnetic field is a weak one Moreover, the magnetic field changes over a period of years Many explanations have been offered to account for the magnetism of the earth It is now generally believed that the magnetic field is due to the electric currents circulating in the earth's interior. It is presumed that these currents take place in the fluid outer core of the earth. The magnetic behaviour at a place due to the earth's magnetism can be known if three quantities are known. These are (a) the *declination*, (b) the *angle of dip*, and (c) the horizontal component of the earth's magnetic field. These three quantities are called magnetic elements of the earth's magnetism.

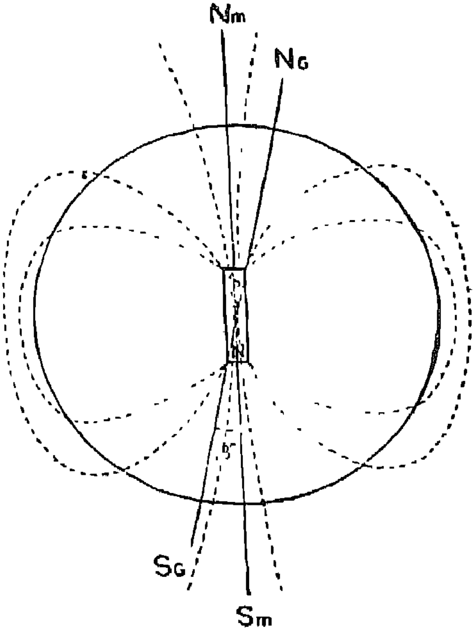


Fig 26.8 The pattern of the earth's magnetic field (approximate)

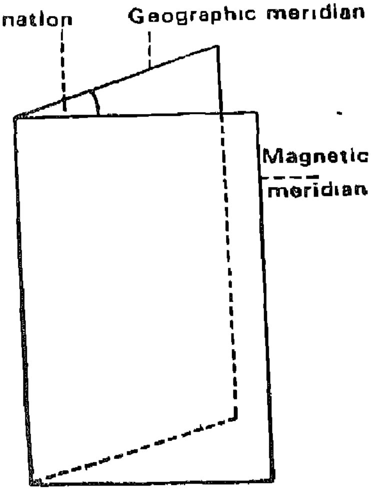


Fig. 26 9 The angle of declination

(a) *The declination*

The vertical plane passing through the axis of a freely suspended magnet is called the *magnetic meridian* at that place. The angle between the magnetic meridian and the geographic meridian at a place is called the *declination* (Fig. 26.9). The knowledge of the declination at a place helps in the determination of the geographical directions at that place.

(b) *The angle of dip*

If a magnetic needle is brought to the magnetic south pole, the needle will stand almost vertically with its north pole pointing downwards. At this position the north pole of the magnet is attracted more by the earth's south pole than by

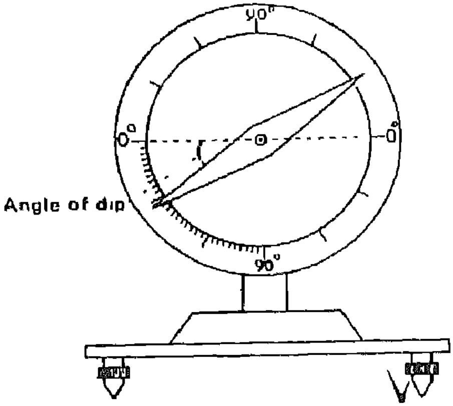


Fig 26 10 A dip circle

its north pole. At the geographical south pole, the south pole will stand vertically. In the equatorial region, the magnetic needle remains horizontal But in any other position on the surface of the earth, the needle will align itself along the direction of the earth's magnetic field. So, the axis of the needle will remain inclined in any other position on the earth's surface. The angle between the axis of a freely suspended magnetic needle and the horizontal plane at a place is called the *angle of dip* at the place (Fig. 26.10). The angle of dip at the poles is 90° and at the equator, zero degree. The line passing on the earth's surface having the zero dip is called the *magnetic equator* The magnetic equator passes through Thumba in South India where space research station has been installed.

EXERCISES

1. **Give reasons for the following :**
   (a) **A freely suspended magnet, in general, is inclined to the horizontal.**

(b) A freely suspended magnet always points in the north-south direction.

(c) A freely suspended magnet remains horizontal near the magnetic equator and vertical near the poles.

2. The earphone of a telephone converts
   (a) electric energy into sound energy.
   (b) electric energy into mechanical energy.
   (c) mechanical energy into electric energy.
   (d) sound energy into electric energy.
3. The magnetic field at a point associated with a current-carrying conductor is
   (a) directly proportional to the current flowing.
   (b) directly proportional to the distance from the conductor.
   (c) inversely proportional to the current flowing.
   (d) independent of the current and the distance.
4. What is meant by the angle of declination at a place ? What is its significance ?
5. A current-carrying conductor is concealed inside a wall. How would you locate it ?
6. State and explain the principle of a dynamo.
7. What are magnetic elements ? Explain with a diagram for each of them.

Chapter 27

Solutions and Electrolytic Dissociation

One of the most useful properties of water is its ability to dissolve other substances to give rise to *aqueous solutions*. A *solution* is a homogeneous material which may not have a definite composition. For example, we can dissolve different amounts of sugar in a given mass of water to obtain solutions of different *concentrations*. On the surface of the earth, oceans form the largest mass of naturally occurring solutions. Sea water contains a number of salts dissolved in water. It was in the oceans that life began on earth and then evolved into various forms. It is not surprising therefore, that the composition of our body fluids is somewhat similar to that of sea water. Solutions show some common properties, which will be discussed in this chapter. To start with, let us examine the physical process by which solutions are formed.

27.1 How are solutions distinguished from suspensions and colloids ?

The process by which particles (molecules, atoms or ions) of one substance (*dispersed substance*) are scattered around the molecules of another substance (*dispersion medium*) is called *dispersion*. Dispersions may give rise to a homogeneous (*solution*) or heterogeneous material (a *suspension* or a *colloid*) The distinction lies in the size of the dispersed particles.

In a suspension, the particle size is of the order of 10^{-5} cm or larger. The particles can be seen as distinct from the dispersion medium by naked eye or under an ordinary microscope. The suspensions are not very stable and the dispersed substance tends to separate from the dispersion medium. Some typical examples are muddy river water and smoke in air.

If the particle size is smaller than 10^{-5} cm (in general 10^{-7} to 10^{-5} cm), the dispersed particles show very little tendency to separate. They can be seen under a special type of microscope only. Such stable dispersions are referred to as colloids. Milk, gum and blood are typical colloids.

In a solution, the particles are of molecular dimensions (smaller than 10^{-7} cm) Solutions are transparent and homogeneous.

Types of solutions: Most common solutions are liquids, for example, brine (a solution of sodium chloride in water), carbonated water (a solution of carbon dioxide in water) and various tinctures (solutions of different medicines in alcohol) used in medicine. These are solid-liquid or gas-liquid solutions. On the other hand, air may be considered a gas-gas solution (nitrogen, oxygen, carbon dioxide, water vapour, etc.) When water is added to alcohol, we get a liquid liquid solution. We can also have a solid-solid solution, as in various coins.

That component of a solution which is present in larger amount is generally referred to as the *solvent*. The other component is called *solute*. There may be more than one solute in a given solution.

27.2 Are there any energy changes accompanying dissolution ?

We have learnt above that in the process of dissolution the solute disperses into single molecules. Thus, the forces of interaction between these molecules are disrupted. Some other forces of interaction between the solute and solvent molecules come into play. It is expected, therefore, that some energy changes will accompany the formation of a solution. Thus, when ammonium chloride is dissolved in water, there is lowering of temperature. When sodium hydroxide is dissolved in water, the solution gets heated up.

27.3 What is solubility of a substance ?

There is a limit to which any substance can be dissolved in a given amount of the other substance. The maximum mass of a substance that dissolves in 100 g of a solvent under particular conditions of temperature and pressure is referred to as the *solubility* of that substance in that solvent under the specified conditions. The solution so obtained is said to be a *saturated solution*.

Solubility varies with temperature and other conditions. The *temperature-dependence* of the solubility of some salts in water is shown in Fig. 27.1. Note

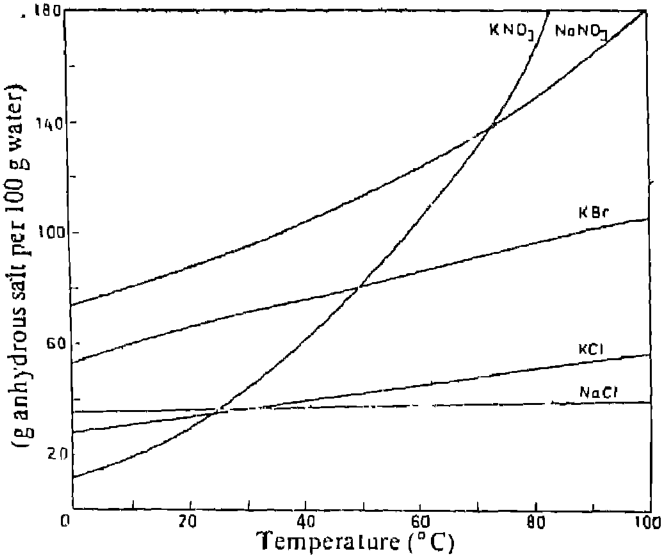


Fig. 27.1 Solubility of some salts in water at different temperatures

that, in general, the solubility increases with a rise in temperature.

For liquid-liquid solutions, two types of behaviour are noted. Some liquids *dissolve* in each other in unlimited quantity, as in the case of water and alcohol. Such liquids are said to be completely *miscible*. In other cases, they *dissolve* to a limited extent only, i.e. they are *partially miscible*. When the solubility is negligibly small, they are said to be *immiscible* liquids.

The solubility of a gas in a liquid decreases with a rise in temperature or fall in pressure. Aerated water contains carbon dioxide dissolved in water at high pressure. That is why when a bottle of cold aerated water is opened, ome of the dissolved carbon dioxide comes out as a result of release of pressure. f it is allowed to warm up slowly to room temperature, more of carbon dioxide released.

4 How are concentrations of solutions expressed ?

In the previous section we have discussed the limits of solubility, i e. we have considered saturated solutions only. The solutions which we generally come across are not saturated. They contain lesser amounts of the solute. The composition of such solutions is expressed as *concentration* which refers to the quantity of a solute dissolved in a definite weight or volume of the solution. The concentration may be expressed in terms of either mass or moles of the solute. The number of moles of a solute present in one litre of a solution is called the *molarity* of that solution. Thus, when 180g (1 mole) of glucose ($C_6H_{12}O_6$) is dissolved in water to make the final volume of solution to one litre, we get a *molar* (or 1 M) solution of glucose. Similarly, one litre of a molar solution of urea (CH_4ON_2) contains 60g of the solute. If there are 120 or 6.0g urea in one litre solution, the molarity will be 2 or 0.1, respectively.

Problem 27.1

5 85g NaCl are present in 100 ml of its solution. What is the molarity of the solution ? (Na=23, Cl=35.5)

Solution

Molecular mass of NaCl=23+35.5=58.5

Concentration=5 85 g per 100 ml

or 58.5g per 1000 ml

$$\text{Molarity}=\frac{58.5}{58.5}=1.0$$

A solution is generally prepared in a pure solvent. In the laboratory, we use mostly aqueous solutions for which it is necessary to use pure water. Natural ground water (from a river or well) has some soluble impurities. These are dissolved from the rocks with which the water came in contact. Therefore, in the laboratory we use distilled water for preparing solutions. By the process of distillation, we can remove all the dissolved or suspended impurities. For several commercial purposes, water need not be distilled but some other purification steps are required. These are described in the following pages.

27.5 What are hard and soft water ?

For most practical purposes, it is not necessary to remove all the dissolved matter. However, certain types of soluble impurities interfere with specific uses. For example, we know that some samples of water lather easily with soap and others do not. These are called soft and hard water, respectively. Hard water contains salts of calcium and magnesium which form precipitates with soap and thereby prevent lather formation. When Ca^{2+} and Mg^{2+} ions are removed (or are replaced by Na^+ ions which do not react with soap), the water becomes soft. The process is called *softening* of water or *removal of hardness* of water.

Water may be softened by various procedures, which depend on the nature of salts present. For example, if calcium and magnesium are present as

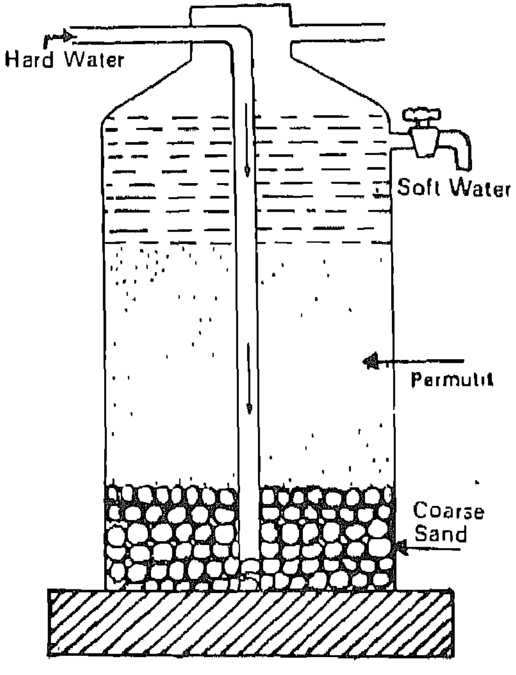


Fig. 27.2 Softening of water by permutit process

bicarbonates, they may be removed by simple boiling. The bicarbona decomposed to carbonates which, being insoluble in water, are precipitate

$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$

$Mg(HCO_3)_2 \rightarrow MgCO_3 + H_2O + CO_2$

For large-scale operations, the treatment invariably involves replac of Ca^{2+} and Mg^{2+} ions by Na^+ ions. For this purpose, water is passe *zeolite* or *permutit*. These are insoluble sodium salts of complex compo which may be represented as Na_2Z. They can exchange Ca^{2+} and Mg^{2+} i water with Na^+ ions which are derived from sodium zeolite. As a result, ca and magnesium zeolites are formed. After use for some time, sodium gets converted into calcium and magnesium zeolites. It is then treated solution of sodium chloride to convert it into sodium zeolite (*regeneratio* use again.

A simple arrangement for water softening by the permutit pro shown in Fig. 27.2.

ELECTRICAL CONDUCTIVITY ELECTROLYTES AND NON-ELECTROLYTES

27.6 What is electrical conductivity of solutions ?

Electrical conductivity can be qualitatively detected with the hel simple apparatus shown in Fig. 27.3.

The bulb lights up when the wires (*electrodes*) are dipped in s chloride solution but not when these are dipped in distilled water or a sc

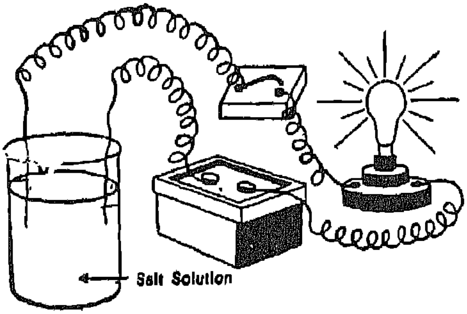


Fig. 27.3 Apparatus for detecting electrical conductivity

of cane sugar. Thus, distilled water and a solution of cane sugar do not conduct electricity, whereas a solution of sodium chloride is a good conductor of electricity. The difference between sodium chloride and cane sugar lies in their molecular structure. We have read earlier that sodium chloride is an electrovalent compound containing Na^+ and Cl^- ions which are held together by electrostatic forces. This force is weaker in water. Consequently, they exist and move independently in water solution. These ions function as carriers of electricity in the solution. On the other hand, cane sugar is a covalent and neutral compound which cannot function as a carrier of electricity. Sodium chloride is an *electrolyte* and cane sugar is a *non-electrolyte*. In general, substances which give rise to ions in solutions are *electrolytes* and those which cannot do so are *non-electrolytes*.

27.6—1 What are weak and strong electrolytes ?

All electrolytes do not conduct electricity to the same extent. If the bulb of Fig. 27.3 is replaced by a galvanometer, we can measure the conductivities of different solutions We find that 1 M hydrochloric acid conducts electricity better than 1 M acetic acid solution. As the electric current is carried through a solution by the ions, we can conclude that 1 M hydrochloric acid furnishes more ions than 1 M acetic acid. Thus, although both are electrolytes, hydrochloric acid is a strong electrolyte and acetic acid is a weak electrolyte.

Many of the properties of solutions of electrolytes are due to the ions resent in these solutions. Consequently, those substances which produce the ne ions exhibit common properties. All acids give rise to hydrogen ions. ese ions occur in combination with water as hydronium ions (H_3O^+). The formation from hydrochloric and acetic acids (i e. their dissociation) is own in the following equations.

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

$$CH_3COOH + H_2O \rightarrow H_3O^+ + CH_3COO^-$$

It is not surprising, therefore, that all acids exhibit some common propers, like their action with (a) indicators, (b) metals, (c) metal oxides, and bases. The strength of an acid depends on the extent of ion formation.

Similarly bases also exhibit some common properties, like reaction with cids. It is due to the formation of hydroxide (OH^-) ions by the bases as in he following equations.

$NaOH \rightarrow Na^+ + OH^-$

$NH_4OH \rightarrow NH_4^+ + OH^-$

Salts are ionic substances which can be formed by reaction of acids with bases. All salts are electrolytes. Therefore, their properties in solutions are the properties of their ions. For example, the solution of silver nitrate ($AgNO_3$) contains silver (Ag^+) and nitrate (NO_3^-) ions. Silver ions have the property of reacting with chloride (Cl^-) ions to form insoluble silver chloride ($AgCl$). Therefore, a white precipitate is obtained whenever solution of a chloride (HCl, $NaCl$, KCl, etc.) is added to that of silver nitrate.

$Ag^+ + Cl^- \rightarrow AgCl$

Water itself dissociates to a very small extent to produce hydronium and hydroxide ions. The concentration of these ions in pure water is exceedingly small.

$2H_2O \rightarrow H_3O^+ + OH^-$

In pure water, both these ions are present in equal concentrations. In acidic and basic solutions, there is an excess of hydronium and hydroxide ions, respectively. Thus the acidic, basic or neutral character of a solution depends on the ratio of concentrations of these ions. This is explained in the next chapter.

27.7 What is electrolysis ?

We have already learnt that in an electrolyte solution, ions serve as carriers of electric current. If the applied voltage is high enough, we can observe some interesting chemical reactions at the two electrodes. When the current is passed, the negatively charged ions, called *anions*, move towards the positive, electrode the *anode*. Similarly, the positively charged ions, the *cations*, move towards the negative electrode the *cathode*. The ions give up their charges to the respective electrodes and become electrically neutral. The neutral species then undergo further reactions to give molecular species. For example, the following reactions take place on passing electric current through molten sodium chloride.

At cathode : $Na^+ + e \rightarrow Na$
At anode : $Cl^- \rightarrow Cl + e$
$2Cl \rightarrow Cl_2$

This process of *decomposition of electrolytes at electrodes by passage of electric current is called electrolysis.*

27.7—1 What are the applications of electrolysis ?

Electrolysis finds a number of applications in the industry. Some examples re given below.

(1) *Electroplating:* Electroplating is a process of coating articles of cheaper netal by a less reactive metal by electrolytic procedure. It is carried out both or decoration as well as protection (against corrosion). For example, an article nade of iron may be coated with nickel. For this purpose, the article is dipped n a solution of a nickel salt (e g nickel ammonium sulphate) and is made the athode. Anode is made of pure nickel metal. On passing electric current, ickel is dissolved from anode and is deposited on the article (cathode).

(2) *Manufacture of metals:* As mentioned in the previous chapter, several netals are obtained by electrolysis of their compounds, e g. sodium and luminium are manufactured by the electrolysis of fused sodium chloride and lumina (dissolved in cryolite), respectively.

(3) *Refining of metals.* Some metals, e g., copper, are refined by the nethod of electrolysis.

(4) *Manufacture of compounds:* Sodium hydroxide and potassium hydr-xide are manufactured by electrolysis of aqueous solutions of sodium chloride nd potassium chloride respectively.

EXERCISES

1. Classify the following into solutions and colloids : soda water, milk, brine, blood and ink.
2. What is a saturated solution ? Does its composition depend on temperature ?
3. Define molarity of a solution. Two beakers have equal volumes of solutions, one containing 100g of sodium chloride and the other an equal amount of urea. Will their molarities be same or different ?
4. 6.84g of sucrose (molecular mass 342) is present in 200ml of a solution. Calculate its molarity.
5. How is soft water distinguished from hard water ? Give two methods of softening hard water.

6. Distinguish between :
   (i) an electrolyte and a non-electrolyte.
   (ii) a strong electrolyte and a weak electrolyte.
7. Classify the following into non-electrolytes and electrolytes :
   (i) silver nitrate
   (ii) cane sugar
   (iii) potassium chloride
   (iv) glucose
8. Explain the term electrolysis. How is electrolysis useful to us ?

Chapter 28

The Rates of Reactions and Chemical Equilibrium

The chemical reactions with which we are familiar proceed at widely different rates. For example, rusting of iron articles is a slow reaction. The gun-powder in crackers is stable for long periods, but when it is fired it reacts with explosive violence. Also, magnesium ribbon burns at a fast rate once it is ignited. Thus, rates of reactions vary widely from one case to another. Indeed, a given reaction may be speeded up by changing the conditions (e g. heating of magnesium ribbon).

28.1 What is the rate of a reaction ?

The rate of a chemical reaction is defined as the number of moles of the reacting substance converted into products in a unit time in a unite volume. The rate of a reaction depends on a number of factors which are given below.

28.2 What are the factors governing the reaction rates ?

The chemical reactions may be broadly divided into two categories, namely heterogeneous and homogeneous reactions. If the reactants participating in a reaction are in different phases (*Phase* is defined as that three dimensional space in which the chemical composition is uniform) as, for example, in the reaction of an acid with marble, the reaction is referred to as a heterogeneous reaction.

$$CaCO_3(s)+2HCl(aq)\rightarrow CaCl_2(aq)+H_2O+CO_2(g)$$

Such reactions take place at the boundary between the two phases where the reactants come in contact with each other.

n homogeneous reactions, the reactants are in a single phase, which may be gaseous, liquid (including solutions) or solid. Neutralisation of an acid by an alkali is an example of this type of reaction.

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O$

For a chemical reaction to take place, it is essential that the reactant molecules must come in contact with each other. This is achieved by collision of molecules which are constantly in motion. It can be shown that only a small fraction of the collisions between molecules of reactants leads to chemical reaction. Any factor which increases the frequency of molecular collisions will increase the probability of chemical reaction. Consequently, the rate of chemical reaction will be increased. This can be achieved in a number of ways, namely by changing temperature, physical nature (for heterogeneous reactions) or concentrations of the reactants. Some compounds are more reactive than others. Therefore, the nature of the reactants also determines the rate. Another factor which alters the rate of a reaction is the presence of a catalyst. These points are detailed in the following paragraphs.

(1) *Effect of temperature:* It is known that as temperature increases, the rate of reaction also increases. It can be verified by carrying out the reaction between marble and hydrochloric acid at different temperatures. If other factors remain the same, the evolution of CO_2 is faster at higher temperatures.

(2) *Physical nature of reacting substances:* In a heterogeneous reaction, the reaction takes place at the contact area or the boundary between the two phases in which reactants are present. If the contact area is increased, the rate of reaction should also increase. We can verify this by crushing some marble to a coarse powder. We can now take a fixed weight of marble pieces in one test tube and an equal weight of marble powder in another test tube. If equal volumes of acid of the same concentration are added to the two tubes, it is found that the reaction with powder is much more brisk than with large pieces. The powder provides a larger contact area between the reactants. Accordingly, the reaction is faster.

(3) *Effect of concentration:* The rate of a reaction increases as the concentration of reactants is increased. For example, if we treat marble chips with an acid of different concentrations, it is found that the reaction becomes more brisk as the concentration is increased.

(4) *Effect of a catalyst:* The effect of a catalyst can be conveniently demonstrated using the thermal decomposition of potassium chlorate to give oxygen

gas and potassium chloride.

$$2KClO_3 \xrightarrow[\text{Catalyst}]{MnO_2} 2KCl+3O_2$$

This reaction proceeds faster and at a lower temperature in the presence of manganese dioxide. We can take equal amounts of potassium chlorate in two hard glass boiling tubes. In one tube we add some manganese dioxide (MnO_2) and mix it with potassium chlorate. Both the tubes are then fitted in an apparatus. On heating we find that in the presence of manganese dioxide, the oxygen liberation starts at a lower temperature and proceeds more briskly.

If potassium chlorate is not readily available, the effect of catalyst can be easily demonstrated by taking hydrogen peroxide and manganese dioxide.

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O+O_2$$

(5) *Chemical nature of the reactant:* Some metals react with oxygen very much faster than others. For example, a piece of sodium or potassium metal will catch fire, if left in the atmosphere On the other hand, gold is not attacked. In between these two extremes are other metals which react with oxygen at different rates. Similarly, acids attack metals at different rates. We have read about these reactions in an earlier chapter.

In the preceding paragraphs we have discussed the factors influencing the rates of chemical reactions. We shall now discuss the extent to which a reaction can proceed.

28.3 What are reversible and irreversible reactions ?

It can be shown that most chemical reactions can proceed in both directions. For example, if super heated steam is passed over red hot iron we get iron oxide and hydrogen.

$$3Fe+4H_2O \rightarrow Fe_3O_4+4H_2$$

On the other hand, when hydrogen is passed over hot iron oxide, iron and water vapour are produced.

$$Fe_3O_4+4H_2 \rightarrow 3Fe+4H_2O$$

Such a reaction, which proceeds in both directions is called a *reversible reaction*. We can write a combined chemical equation for the above two reactions as shown on the following page.

$$3Fe + 4HO_2 \rightleftharpoons Fe_3O_4 + 4H_2$$

The double arrow shows that the reaction can proceed in either direction. Indeed, most chemical reactions are reversible. We generally devise the conditions in such a way that it should go to completion in the desired direction. For example, in the first case, hydrogen is swept away together with passing steam so that it is not available for the reverse reaction. Similarly, water vapour is swept away in the second reaction.

If the above reaction is carried out in a closed vessel, all the four reactants can be detected in the reaction mixture. After some time, the composition of the mixture becomes constant. The reaction is said to have attained a state of *equilibrium*.

Reversibility of chemical reactions and attainment of the state of equilibrium can be demonstrated with almost all the reactions. In some cases it is more obvious than in others. One good example is the thermal dissociation of hydrogen iodide to give hydrogen and iodine.

$$2HI \rightleftharpoons H_2 + I_2$$

Hydrogen iodide gas can be heated to various temperatures and the resulting mixture analysed for the various components Alternatively, we can heart mixtures of hydrogen and iodine vapour to the required temperature and again analyse the mixture. We find that the composition of the final mixture under given conditions of temperature and pressure is the same whether we start with HI or with H_2 and I_2.

In some cases, the equilibrium lies very far in one direction so that the reaction is practically irreversible, e.g., burning of hydrogen in oxygen to form water.

28.4 Can we apply the law of mass action to the equilibrium state ?

Let us consider a general reaction at equilibrium.

$$A + B \rightleftharpoons C + D$$

Let the concentrations of A, B, C and D be [A], [B], [C] and [D] moles per litre respectively. According to the law of mass action, the rate of the forward reaction $\propto [A][B] = K_f[A][B]$ where K_f is a constant. It is known as the rate constant Similarly the rate of reverse reaction $[C][D] = K_r[C][D]$ where K_r is the rate constant for the reverse reaction. At equilibrium, the rate of forward reaction is equal to the rate of reverse reaction.

$$K_f[A]\,[B] = K_r[C]\,[D]$$

$$\text{or} \quad \frac{K_f}{K_r} = \frac{[C][D]}{[A][B]} = K$$

As K_f and K_r are constants, their ratio should also be a constant. The ratio of rate constants for forward and backward reactions is equal to the equilibrium constant (K) of the reaction.

Dissociation of water and pH scale: Let us apply these considerations to a familiar system, namely the dissociation of water molecules into H^+ and OH^- and to the acidic and alkaline solutions.*

$$H_2O \rightleftharpoons H^+ + OH$$

According to the above relationship, we can write the following equilibrium equation:

$$K = \frac{[H^+]\,[OH^-]}{[H_2O]}$$

In aqueous solutions, the concentration of water molecules is very large and does not change significantly when acids or alkalies are dissolved. Therefore, we can write another equation as follows:

$$[H^+]\,[OH^-] = K \times [H_2O] = K_w \text{ (Ionic product of water)}$$

Thus the product of concentration of H^+ and OH^- is constant at a given temperature. At 25°C, this product is approximately equal to $10^{-14}\ M^2$. The small value of K_w shows that water is dissociated to a very small extent only. That is why pure water is a bad conductor of electricity.

In acidic solutions, the concentration of H^+ is very large. The concentra- n of OH^- decreases so that the product of the two concentrations remains stant at 10^{-14}. In alkaline solutions, the concentration of OH is high. erefore, the concentration of H^+ must decrease to maintain the value of K_w nstant. In both cases, the decrease in concentrations of H or OH^- is achieved y reversal of the dissociation of water.

Thus, we see that the concentrations of H^+ and OH^- are related to each ther. If one of them is defined, the other is automatically fixed. The chemists se a logarithmic scale for denoting the H^+ concentration. It is known as the

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*In this equation H^+ is shown to exist independently. It actually exists as H_3O^+. This difference, however, does not affect the conclusion. The approach given here has the advantage of simplicity.

pH scale. The *pH* of a solution is defined as follows :

$$pH=\log\frac{1}{[H^+]}=-\log[H^+]$$

In a neutral solution, the concentrations of H^+ and OH^- are equal. According to our above discussion, these will be equal if each is equal to 10 M (so that the product is equal to $10^{-14}M^2$). The *pH* of a neutral solution should, therefore be

$$-\log(10^{-7})=-(-7)=7$$

If H^+ concentration increases to 0.1M, that of OH^- will decrease to 10^{-13}M. The *pH* of this acidic solution will be

$$-\log(0.1) \text{ or } -\log(10^{-1})=-(-1)=1$$

If OH^- concentration increases to 0.1M, that of H^+ will become 10^{-13}M. The *pH* of this alkaline solution will be

$$-\log(10^{-13})=-(-13)=13$$

Thus, we see that the *pH* values of acidic, neutral and alkaline solutions are in the following order :

Acidic solution $pH<7$
Neutral solutions $pH=7$
Alkaline solutions $pH>7$

28.5 What is the effect of temperature on equilibrium constant ?

In the definition of equilibrium constant above, the temperature was considered to be constant. We find that temperature has a pronounced effect on the equilibrium constant. In a general way, the endothermic reactions, in which heat is absorbed, are favoured at high temperatures. For example, nitrogen and oxygen combine at high temperatures to form nitric oxide

$$N_2+O_2+\text{heat}\rightleftharpoons 2NO$$

Similarly, exothermic reactions in which heat is given out are favoured at low temperatures, e.g. the formation of ammonia from nitrogen and hydrogen.

$$N_2+3H_2\rightleftharpoons 2NH_3+\text{heat}$$

28.6 What is Le Chatelier's principle ?

The common ion effect and the effect of temperature stated above follow from generalized principle given by the Le Chatelier (1888) which is known by his name. It states that :

If a system at equilibrium is subjected to a constraint (i.e. a change in temperature, pressure or concentration), the system adjusts itself to counteract that constraint.

From it, we can infer the following :

(i) If the concentration of a component of a system at equilibrium is increased, the system will adjust itself to counteract this increase. For example, the suppression of dissociation of water on the addition of H^+ or OH^- ions (Common ion effect);

(ii) An endothermic reaction will be favoured at high temperature;

(iii) An exothermic reaction will be favoured at low temperature;

(iv) A gas-phase reaction in which the number of molecules on the product side is less than that on the reactant side will be favoured by the increase of pressure;

(v) The gas-phase reaction in which the number of product molecules is larger than the number of reactant molecules will be favoured at lower pressures.

This principle is very useful for a qualitative prediction of the direction of change of a chemical reaction consequent to some changes in conditions (of temperature, pressure and concentration).

28.7 Some industrially important equilibrium reactions and their catalysts

The results of the studies of (i) equilibrium of various reactions, and i) the effect of different parameters have been applied to numerous industrial ocesses Conditions have been worked out to obtain maximum yields (or onversion) at fast rates. Two examples are given below :

(1) *Manufacture of ammonia by Haber's process* The reaction between nitrogen and hydrogen is represented by the following equation :

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + \text{heat}$$

In this reaction, one molecule of nitrogen and three molecules of hydrogen combine to give two molecules of ammonia. The number of molecules decreases with the formation of ammonia. According to Le Chatelier's principle, the formation of ammonia should be favoured at high pressure. Further, the reaction is exothermic. It should, therefore, be favoured at low temperature. However, if the temperature is kept low the reaction proceeds at a slow rate. A compromise is struck between these two factors and the reaction is carried out at a moderate temperature around 500°C. The reaction is speeded up by using a catalyst, which is mainly iron mixed with a little molybdenum Heat evolved during the reaction helps to maintain the temperature of reaction vessel at the desired value A high pressure of about 350 atmospheres is used to favour the formation of ammonia. Under these conditions, about 30% of the reactants are converted into ammonia. The product, ammonia, can be separated from unreacted mixture of nitrogen and hydrogen because it can be readily liquified. Under these conditions, nitrogen and hydrogen remain in the gaseous state. The unreacted mixture is compressed, heated and passed again over the catalyst

(2) *Manufacture of sulphuric acid by contact process:* In this process sulphur dioxide is first obtained by burning sulphur or by roasting pyrites After purification, sulphur dioxide is mixed with air and passed through heated iron tubes containing vanadium pentoxide catalyst at about 400°C Sulphur dioxide gets oxidised to sulphur trioxide.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 + \text{heat}$$

Note that in this case also, low temperature should favour the reaction but would slow down the approach to equilibrium. Therefore, the reaction is carried out at a moderate temperature in the presence of a catalyst.

Sulphur trioxide so formed does not dissolve readily in pure water. It reacts more readily with concentrated sulphuric acid to form pyrosulphuric acid or oleum.

$$H_2SO_4 + SO_3 \rightarrow H_2S_2O_7$$

Oleum is then allowed to react with water to get pure sulphuric acid.

$$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$$

In practice, the two reactions are carried out simultaneously. Water is added to the absorbing acid at a regulated rate so that the concentration of acid is maintained constant at the desired value.

EXERCISES

1. Mention the factors which influence the rate of a chemical reaction.
2. Give equations for the following reactions. In each case, mention

whether it is reversible or practically irreversible.

(i) Iron and steam (ii) Sodium and chlorine

(iii) Hydrogen and iodine (iv) Sodium and water

3. Which will react at a faster rate ? Give reasons for your answer.
   (i) Zinc lumps or powdered zinc (with hydrochloric acid)
   (ii) Hydrochloric acid at room temperature or at 10°C below room temperature (with calcium carbonate)
   (iii) 2.0M hydrochloric acid or 2.5M hydrochloric acid (with calcium carbonate)
   (iv) A piece of sodium or a piece of copper (with air).
4. What does *pH* of a solution signify ? Three solutions *A*, *B* and *C* have *pH* values 4, 6 and 10, respectively. Arrange them in increasing order of acidity.
5. State Le Chatelier's principle Explain its application in devising optimum conditions for
   (i) Haber's process for the synthesis of ammonia; and
   (ii) Contact process for the manufacture of sulphuric acid.

Chapter 29

Combustion and Fuels

Fire, which is a form of heat energy today, was a complete mystery to primitive men. It was a cause of fear for them. They believed that it was due to the Fire God, a supernatural power.

It is said that civilization began when man learnt to produce fire, control and use it for cooking, making tools, vessels and weapons, etc. to make life comfortable

29 1 What is combustion ?

The experiments of Lavoisier and others have proved that substances burn in the oxygen of the air to form oxides. Let us study the burning of a few substances like sulphur, magnesium, phosphorus and carbon in air (oxygen). The reactions are :

$$S + O_2 \rightarrow SO_2 + \text{Heat}$$
$$2Mg + O_2 \rightarrow 2MgO + \text{Heat}$$
$$P_4 + 5O_2 \rightarrow P_4O_{10} + \text{Heat}$$
$$C + O_2 \rightarrow CO_2 + \text{Heat}$$

In all these cases (i) oxides are formed, and (ii) large amount of heat is liberated. The reaction is generally accompanied by emission of light.

The process of burning in oxygen (called oxidation) accompanied by liberation of heat) and light is called *combustion*.

It is not always necessary that burning or combustion should only be in oxygen. We know that antimony burns in chlorine and magnesium burns in nitrogen producing much heat and light.

$$2Sb + 3Cl_2 \rightarrow 2SbCl_3 + \text{Heat}$$
$$3Mg + N_2 \rightarrow Mg_3N_2 + \text{Heat}$$

Both these reactions are oxidation reactions with the production of heat and light and as such are examples of combustion.

29.2 What are the conditions necessary for combustion ?

We know that substances like paper, dry grass, camphor, spirit, kerosene oil, etc. burn easily whereas stone, glass, etc. do not burn.

(i) Substances which burn easily are called *combustible* substances.

(ii) Substances which do not burn are called *non-combustible* substances.

Thus, the first condition necessary for combustion is the presence of a combustible substance. That is why when fire breaks out, we remove combustible materials from nearby places so that fire may not spread.

In our homes if some burning coal or wood is left after cooking, we generally cover these coal or wood pieces with some vessel. After a while coal or wood pieces stop burning. Similarly, when the clothes of a person catch fire, we roll him in blanket to extinguish fire. This is done in order to cut off the supply of air and stop the combustion of these materials. We already know that a burning candle if covered with a glass jar is extinguished after some time because supply of air (oxygen) is cut off. It can, therefore, be concluded that the presence of a combustible substance is not sufficient for burning but a supporter of combustion like oxygen is also essential. Thus, second essential condition for burning is the presence of a supporter of combustion.

We know that in our homes some other materials are required to ignite soft coke in a hearth A burning match stick is first applied to burn pieces of paper and the fire so produced is used to burn wooden pieces. The flames of wooden pieces are then able to start fire in soft coke. Why do we do all this to burn soft coke ? Why can we not burn the coke directly with a burning match stick ?

Let us take three labelled hard glass test tubes, each containing 1 ml of methylated spirit. 1 ml of kerosene oil and about 1 g paraffin wax separately. Bring a burning splinter in contact with each of the three substances and observe what happens. Only the methylated spirit catches fire. Now heat the other two test tubes slowly. Hold a burning splinter again at the mouth of these test tubes. It will be observed that kerosene oil vapours catch fire easily than those of wax vapours. It can, therefore, be concluded that these substances catch fire at different temperatures. The lowest temperature at which a substance catches fire is called its *kindling (ignition) temperature* Kindling temperature is, therefore, a characteristic property of a combustible substance Now we have understood why a burning match stick cannot start fire in soft coke

Thus, attainment of kindling temperature is also a condition for combustion

For combustion we require

(1) a combustible substance,
(2) a supporter of combustion (normally oxygen of air); and
(3) attainment of kindling temperature of the substance.

In the absence of any one of these three conditions, combustion will not take place.

29 3 What are the different types of combustion ?

If a burning splinter is taken near the gas burner of the laboratory and the tap of the gas is opened, the gas immediately starts burning with the production of heat and light. Oxidation reactions in which light and large amount of heat are produced in a short time are called *rapid combustions*.

A very small piece of white phosphorus is dissolved in carbon disulphide. A piece of filter paper is then dipped in this solution. The filter paper piece is held with a pair of tongs and waved slowly in air. Carbon disulphide, being a volatile substance, evaporates slowly and after a short time the filter paper piece bursts into flames. What has happened ? During the process of dissolution the white phosphorus is dispersed in carbon disulphide. When carbon disulphide is evaporated, each tiny particle of white phosphorus gets oxidised by the oxygen of air with the evolution of some heat. This heat is accumulated till the kindling temperature of white phosphorus is reached. On attaining this temperature, phosphorus started burning causing also the paper to burn with the production of heat and light Such a combustion which takes place without the application of any external heat is known as *spontaneous combustion*. Spontaneous combustion of coal dust has resulted in many disastrous fires in coal mines.

Certain crackers explode only when pressure is applied Oxidation of the chemicals in cracker takes place at a very high speed. Large volume of gases are liberated with the evolution of tremendous amount of heat and light. Similar is the case of a gun shot when fired Such a process of combustion, is called *explosion*.

29.4 How do we extinguish fire ?

We have already learned that there are three essential requirements for producing fire and it can be extinguished by removing any one or more of these. Fire can be extinguished by

(i) starving it by removing nearby combustible substances;
(ii) smothering it by cutting off the supply of air;
(iii) cooling it by lowering the temperature of combustible substances below their kindling temperatures.

29.4—1 Fire extinguishers

To extinguish fire, even on large scale, the above three principles are being applied by fire fighters. Fire extinguishers are built up on the principle of smothering and/or cooling the fire. Common fire extinguishers in use today are :

(i) *Water as a fire extinguisher* (*based on the principle of cooling the fire*): Whenever a fire breaks out, the fire brigade cools the fire by throwing water on it under high pressure. The water cools the combustible substance below its kindling temperature and the fire is extinguished. The water vapours also surround the combustible material and thus help in cutting of the supply of air.

Oil fire should not be extinguished by throwing water on it. Water, being heavier than oil, will settle down and oil will continue to burn. In case of electrical fires, water is not used at all as it conducts electricity and this may result in *electrocution*.

(ii) *Soda-acid fire extinguisher* (*based on the principle of cooling the fire*) : Construction and constituents of this extinguisher are shown in Fig 29 1 (a). We see a knob in the extinguisher. When this knob is pressed hard it strikes the glass bottle and the bottle breaks, sulphuric acid comes in contact with sodium bicarbonate solution and reacts to liberate carbon dioxide Fig. 29.1(b). The pressure of carbon dioxide forces a stream of liquid out to a considerable distance. The carbon dioxide dissolved in water is of some benefit in putting out the fire but water is the main extinguishing agent which lowers down the temperature of the combustible substance below its kindling temperature.

(iii) *Foam type fire extinguisher* (*based on the principle of smothering the fire*). This fire extinguisher is similar in construction to the soda-acid fire extinguisher. However, the sodium bicarbonate solution in this case contains Turkey red oil. On operation, carbon dioxide is liberated under pressure in the

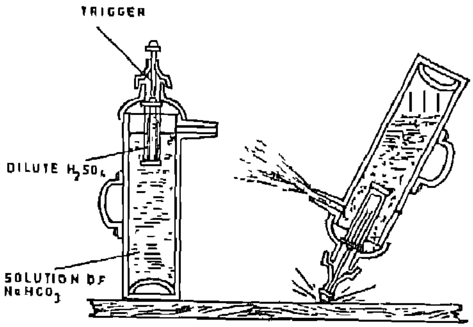


Fig. 29.1 Soda-acid fire extinguisher

form of foam. The Turkey red oil prevents the escape of the gas by stabilising the foam. The foam covers the whole surface of the oil and thus cuts off the supply of air and the fire is extinguished. This type of extinguisher is used for oil fires. Airports and petrol pumps use this extinguisher.

(iv) *Carbon tetrachloride fire extinguisher* (*based on the principle of smothering the fire*): This extinguisher contains the volatile organic liquid—carbon tetrachloride. When it is pumped out, it vaporises and being much heavier than air, envelopes the fire and the combustible substance. The vapours of carbon tetrachloride cut off the supply of air. This is used for extinguishing fires caused by electricity. This extinguisher should not be operated in closed rooms, because carbon tetrachloride vapours are likely to produce a poisonous gas, phosgene, while in contact with metals. It is advisable to use wet clothes on mouth and nose to protect from the effect of carbon tetrachloride vapours.

29.5 What are fuels ?

We need heat energy for domestic and industrial purposes. Most of this heat is obtained from burning of substances like wood, coal gases, petrol, etc.

The material that is burnt for producing heat energy is called a *fuel* Thus, coal, wood, domestic gas, petrol, etc. are fuels.

Fuels are found in three states—solid, liquid and gas. Some common fuels are listed in Table 29.1,

TABLE 29.1

Some Fuels

Solid fuels	*Liquid fuels*	*Gaseous fuels*
Coal	Kerosene oil	Natural gas
Coke	Petrol	Petrol gas
Wood	Diesel	Coal gas
Charcoal	Alcohol	Water gas (H_2+CO)
Wax (Paraffin)	Hydrogen (l)	Producer gas ($2N_2+CO$)
		Acetylene
		Hydrogen (g)

29.6 What are the sources and composition of some of these fuels ?

(a) *Solid fuels:*

(i) *Wood.* Trees are the source of wood. Wood is composed of compounds containing mainly carbon, hydrogen, nitrogen and oxygen Wood charcoal is prepared by heating wood in the absence of air (*destructive distillation*) Wood charcoal is largely carbon.

(ii) *Paraffin wax:* It is mainly a mixture of several hydrocarbons ($C_{20}H_{42}$ to $C_{40}H_{82}$). It is obtained by chilling the high boiling fraction of petroleum.

(b) *Liquid fuels:*

Petrol, kerosene oil and diesel are liquids at room temperature, and are a mixture of several hydrocarbons. They are obtained as different fractions during distillation of petroleum.

(c) *Gaseous fuels:*

(i) *Coal gas:* It mainly contains methane, hydrogen and carbon monoxide. It is obtained by the destructive distillation of coal.

(ii) *Producer gas:* It is a mixture of nitrogen and carbon monoxide. It is obtained by passing air over red hot coke.

(iii) *Liquefied petroleum gas (LPG):* It is commonly used for domestic heating purposes. It contains liquefied butane and *iso*-butane mixture.

(iv) *Water gas:* It is essentially a mixture of hydrogen and carbon monoxide It is obtained by passing steam over red hot carbon.

$$C+H_2O \rightarrow CO+H_2$$

29.7 What are the characteristics of a good fuel ?

A large number of combustible substances are known to us. However, not all the combustible substances could be used as fuel A good fuel should have the following characteristics :

(i) fairly cheap;
(ii) readily available;
(iii) readily combustible in a manner that can be controlled;
(iv) free from any dangerous and harmful waste products,
(v) convenient to store and handle;
(vi) having a high calorific value.

There is probably no fuel which could be considered ideal; so we should look for a fuel which fulfils the maximum qualities of a good fuel and serves the purpose for which it is used.

29 8 What is the calorific value of a fuel ?

When a given mass of fuel burns, a definite amount of heat is evolved. Burning of carbon in air can be represented as follows :

$$C+O_2 \rightarrow CO_2+39.35\times10^4 \text{ joules } (94.0 \text{ kcal})$$

Complete burning of 12g carbon releases 39.35×10^4 joules of heat.

Calorific value of a fuel is the amount of heat obtained by burning one gram of that fuel. It is generally expressed in calories (1 calorie=4.1868 joules).

29.9 What is a rocket fuel ?

Today, man has fulfilled his desire of reaching the moon. This has been possible with the help of rockets. These rockets need fuels called propellants which supply energy for propulsion.

Propellants are of two types: (i) liquid propellants, and (ii) solid propellants.

(i) *Liquid propellants:* Liquid propellants consist of a fuel like alcohol, liquid hydrogen, liquid ammonia, kerosene oil, hydrazine, etc Liquid oxygen, liquid fluorine, hydrogen peroxide or nitric acid are used as oxidisers.

(ii) *Solid propellants* A solid propellant is a mixture of oxidising and reducing materials that can co-exist in the solid state at ordinary temperature. It consists of a mixture of hydro-carbons and an oxidiser which may be a chlorate, perchlorate or nitrate.

In our country, Indian Space Research Organization (ISRO), situated at Thumba near Trivandrum (Kerala State), is conducting space researches Such fuels as described above are used there in rocket engines for launching satellites and spaceships.

EXERCISES

1. How are the terms of oxidation and combustion related to each other ? Which of them is a pre-requisite for the other ? Give suitable examples.
2. What are the different types of combustion ? Give one example of each.
3. Describe briefly the different types of fire extinguishers. Draw a cut-away view of any one of them.
4. Name three each of solid, liquid and gaseous fuels used in daily life.
5. Define calorific value of a fuel. What is its importance ?
6. Name some fuels, both solid and liquid, used in rocketry.

Chapter 30

Human Biology, Health and Nutrition

30.1 Functional anatomy of human reproductive system

30.1—1 Male reproductive system

The main male reproductive organs are the testes. The associated or accessory organs are the epididymis, the seminal vesicles, the prostate and the penis (Fig. 30.1).

TESTES

They are two in number. Each testis is oval in shape and lies within a thick fibrous covering which is enclosed in skin, the scrotum.

Each testis contains seminiferous tubules which join to form 15-20 larger tubes opening into the epididymis.

The functions of the testes are to produce spermatozoa and male sex hormones. The process of production and maturation of sperms is called spermatogenesis.

Spermatogenesis: The seminiferous tubules are lined with the germinal epithelium on its inner side. These cells divide a number of times to produce spermatozoa. During these divisions, meiosis occurs Meiosis results in the reduction of number of chromosomes from 46 to 23 in each spermatozoon (sperm). In animals, spermatogenesis occurs only in breeding seasons In man, after puberty, spermatogenesis takes place continuously until it stops in the old age. Spermatogenesis is dependent on the presence of male sex hormones—the androgens. These hormones are produced by the interstitial cells which lie in the interstitial space between the seminiferous tubules. After puberty the hormones are produced in larger quantity.

The anterior pituitary, through the action of its gonadotrophic hormones, controls the functional activity of the testes.

Since sperms are continuously produced they pass into the seminiferous tubules and the larger tubules and then into the epididymis.

EPIDIDYMIS

This is a tube like structure which is firmly attached to the testis and is connected with the seminiferous tubules. Epididymis is the main storehouse for sperms.

A sperm consists of three parts: The head contains nucleus. The middle piece contains mitochondria and is responsible for energy release. The tail is long and the sperm swims in the fluid by means of whiplike action of the tail.

The sperms reaching the epididymis are immature, non-motile and have a very low fertility. In the epididymis, they mature, become motile and develop their fertilising power.

They then pass into the vas deferens. The vas deferens is a tubular structure with a muscular wall with non-ciliated epithelium on the inner side. The sperms partly swim and are mainly moved along by muscular action of the

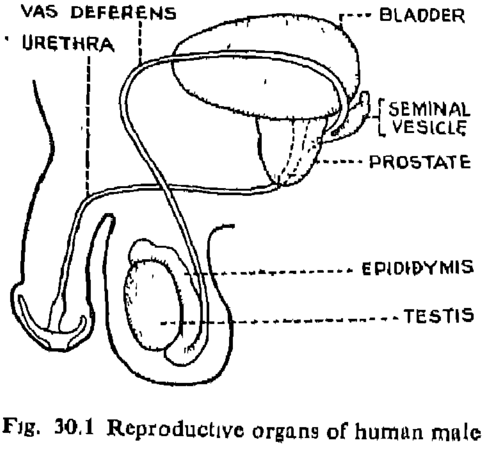


Fig. 30.1 Reproductive organs of human male

wall of the vas deferens. The vas deferens connects the epididymis to the seminal vesicle.

SEMINAL VESICLES

These are a pair of thin walled muscular, elongated and lobulated sacs. They lie at the base of the urinary bladder above the prostate gland. They both join to form the ejaculatory duct.

They secrete a viscous fluid which forms much of the volume of the ejaculated seminal fluid.

PROSTATE

The prostate is closely applied to the urethra towards the urinary bladder. It is of the size of a whole round arecanut and has about two dozen ducts which open into the urethra The prostate produces a fluid—the prostatic fluid—which gives the semen its characteristic odour.

The fluid together with the secretion of the seminal vesicles are released into the lumen of the urethra.

The prostate does not have any counterpart in the female.

URETHRA

The urethra is a muscular tube beginning at the urinary bladder. It passes through the penis to the tip of the glans penis. The urethra is also the passage through which urine is voided. Thus, the male urethra functions both for the reproductive system and for the urinary system.

30.1—2 Female reproductive system

The female reproductive system consists of the two ovaries, the fallopian tubes, the uterus and the vagina (Fig. 30.2).

OVARIES

There are two ovaries Each is an oval body lying in the pelvic cavity. At birth each ovary contains about 250,000—500,000 ova but the majority degenerate during the lifetime. Only about 400 ova mature and are released in a normal human life span. In addition, the ovaries produce two hormones: the oestrogen and the progesterone. These hormones cause a number of changes of

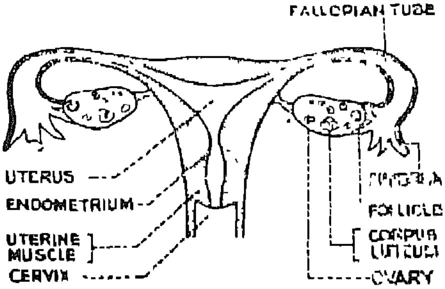


Fig. 30 2 Reproductive organs of human female

which the following are important :

1. Growth and development of the uterus, fallopian tubes and vagina at the puberty.
2. Regular monthly bleeding—the menstrual cycle.
3. Appearance of secondary female sex characters.
4. Changes and development of the mammary glands.
5. Changes that take place during pregnancy.

FALLOPIAN TUBES

The fallopian tubes are muscular tubes which are attached to the uterus at one end. The other end of the fallopian tube expands into finger like projections called fimbriae. This end lies close to the ovary. When the ovary releases an ovum, the fimbriae pick it up and convey it through the fallopian tube to the uterus. In the tube, it is moved along by the ciliary lining of the tube and also partly due to muscular contraction of the wall. If the ovum is fertilised, it develops into an embryo. If it is not fertilised, it is discharged through the cervix and vagina during the next menstrual flow.

UTERUS

The uterus is a hollow muscular organ within which the embryo develops. It lies between the urinary bladder in front and the rectum behind. It is pear shaped and is 7.5 cm in length, 5 cm in breadth and 3.5 cm in thickness. It has a large upper part—the body, and a lower narrow part known as the cervix. The cervix protrudes into the vagina. The fallopian tubes are attached to the upper part of the uterus as shown in Fig. 30.2. The wall of the uterus is thick and muscular and encloses a cavity. The cavity is lined by a layer of cells forming the endometrium. The chief function of the uterus is to provide the place for the ovum, when fertilised, to grow into an embryo.

VAGINA

The vagina is a tube like structure which extends from the vulva to the level of the junction of the cervix with the body of the uterus. The vagina is normally in a collapsed state with the anterior and posterior walls in contact with each other. Vagina acts as a receptacle for the spermatozoa necessary for fertilisation of the ovum.

OVULATION

The ovum with its surrounding layer of cells is called a follicle. Towards the middle of a menstrual cycle one follicle develops rapidly (Table 30.1). The cells multiply and the centre of the follicle degenerates and becomes fluid. As more fluid collects, around the 14th day before the next cycle, the follicle ruptures. The ovum loosens and is discharged from the ovary. This process is known as ovulation.

The ovum is picked up by the fimbriae of fallopian tube and passes through the fallopian tube on its way to the uterine cavity. Before ovulation occurs, only oestrogen circulates in the blood stream. From the second day after ovulation, till another 10-12 days both oestrogen and progesterone are present in the blood stream.

When the ovum has been released, the ruptured follicle heals. The healed follicle without the ovum is called the *corpus luteum* which matures and persists over the next 12-14 days. If the ovum is not fertilised, it degenerates towards the end of the menstrual cycle. If fertilisation occurs, the corpus luteum continues to grow and produces hormones, mainly progesterone, for several months. It starts to degenerate at about the sixth month of pregnancy.

These hormones, i.e. oestrogen and progesterone, are essential for the proper growth of the endometrium The level of hormones falls rapidly during the last three days of the cycle if fertilisation does not occur. Then on the first day of the next cycle bleeding starts with the passage of the endometrial tissue

TABLE 30.1

Ovulation and the Menstrual Cycle

Phases	*Time of cycle*	*Changes in ovary*	*Hormones*	*Changes in the uterus*	*Ovum*
Menstrual	1-4th day	Follicle formation	Oestrogen secretion begins	Shedding of the endometrium with bleeding	Discharged with menstrual flow
Post menstrual or proliferative	5-13th day	Follicle growth and maturation	Oestrogen	5-13th day formation and proliferation of new endometrium	Maturation in the follicle
Ovulation	14th day	Rupture of follicle to release the ovum	-do-	Proliferation of endometrium and increase in the blood supply	Ovum released, picked up by the fimbriae of fallopian tube
Premenstrual or progestational	15-19th day	Transformation of follicle to corpus luteum and its maturation	Oestrogen and Progesterone	-do-	Transport to the uterus Fertilisation may occur
	19-25th day	-do-	-do-	-do-	Implantation of the ovum if fertilisation occurs. If not fertilised, it is expelled
	26-28th day	Degeneration of corpus luteum	Rapid fall in the level of both the hormones	Degenerative changes of endometrium begin	
Menstrual	1st day of next cycle				

and the unfertilised ovum. The endometrium is completely sloughed off in an average of four days time. The sloughed off endometrium and the blood constitutes menstrual flow.

It is important to note that ovulation occurs 14th days before the next menstrual cycle. Thus, ovulation occurs on the 14th day of a 28th day cycle or on the 16th day of a 30-day cycle. The anterior pituitary influences the ovulation through at least three hormones. Hypothalamus of the brain controls the secretion of these gonadotrophic hormones by the anterior pituitary.

30.2 Pregnancy and child birth

30.2—1 Fertilisation

It is estimated that the ovum is not capable of being fertilised 48 hours after ovulation. Spermatozoa also live for approximately 48 hours after discharge. If sperms are introduced into the vagina within 48 hours of ovulation, fertilisation may take place. The sperms swim from the vagina through the cervix and uterus to reach the ovum while it is still in the fallopian tube. About 200 million sperms are discharged in each ejaculation by the male Many sperms die even before reaching the uterine cavity, but many viable sperms reach the ovum However, only one sperm fuses with the ovum. Thus fusion of one ovum and one sperm results in the formation of a zygote. The fertilised ovum reaches the uterine cavity and gets embedded in the endometrium. The corpus luteum of the ovary does not degenerate but proliferates and secretes hormones, mainly progesterone. The endometrium does not undergo degeneration and the menstrual flow does not occur. The female complains of having missed a monthly period and becomes pregnant.

30.2—2 Pregnancy

The duration of pregnancy is, on an average, 280 days or 40 weeks from the last menstrual cycle. During pregnancy certain changes take place in the mother.

The uterus shows the most marked changes. It enlarges in size and reaches the level of the margin of the mother's ribs by the 36th week. The weight of the uterus increases steadily until the delivery of the baby. The blood supply to the uterus increases. The foetus and placenta within the uterus grow in size

Later the foetus can be felt through the abdominal wall. The amniotic fluid, in which the foetus floats, increases in quantity. The abdomen of the expectant mother is distended due to the enlargement of the uterus and its contents Dark lines appear on the abdomen. They form white marks after delivery. The breasts enlarge in size. The nipple and the area around it become darker. They produce a secretion in the late months of pregnancy. After the birth of the baby, milk is secreted for the new born. The expectant mother gains in weight during pregnancy.

Pregnancy puts new demands on the mother since she has to take enough nourishment for herself and for the growing foetus. The extra weight has to be carried by her. There are changes in the composition of her body fluids and circulating hormones. There are some mental and emotional stresses on the mother.

30 2—3 Development of the foetus

When a sperm fertilises the ovum, the product is called a zygote. The zygote undergoes repeated cell division and gets implanted in the endometrium by the 24th day of the menstrual cycle Cell division, which starts even before implantation, continues. By the 4th week a hollow mass of cells is formed.

By the 5th week the mass of cells differentiates into three germinal layers. Each layer later forms different functional organs and systems. This period constitutes the germinal period or germinal stage of the foetus.

The embryonic stage begins with the 6th week when small buds appear for the organs like brain, heart, lung, liver, etc. Buds for the limbs are also formed. By the end of the 6th week a primitive circulatory system is established.

During the next three weeks the hands and feet can be recognised. The organs and systems, *viz* , digestive, respiratory, nervous systems and external sex genitalia, develop during this period.

By the 10th week the embryonic stage is over and the foetal stage begins. By the 12th week all essential features, recognisable in later life, are present, though not fully developed. Between 18-20 weeks, the foetal heart-beats can be heard through the mother's abdominal wall.

During the next eight weeks of pregnancy the foetus continues to grow and the organs mature further. At the end of this period the length of the foetus is about 35 cm and its weight is about 1.3 kg.

From 28-36 weeks there is deposition of fat which gives the foetus a plump appearance. The length of the foetus at this time is about 45 cm and it weighs 2 to 2.5 kg. During the last four weeks, the foetus is fully mature and is delivered around the end of the 10th lunar month or 40 weeks.

30.2—4 Nutrition of the foetus

The foetus derives its nutrition from the mother. All nutrients including oxygen are obtained from the mother's blood stream. The placenta is the organ which develops during pregnancy and is attached to the inner surface of the uterine wall. The umbilical cord attaches the foetus to the placenta. The full-term placenta is 500 to 1000 gm in weight or about 1/7th weight of the foetus. The umbilical cord has two arteries and a vein. These arteries branch and ramify and form a spongy mass which is attached to the uterus. The fine capillaries of the placenta are always bathed in small pools of maternal blood. The maternal and foetal circulations remain distinct, but are separated only by the wall of the capillary through which foetus is able to receive all its nutrients and also transfer nitrogenous waste and carbon dioxide into the maternal blood.

30.2—5 Hazards to the pregnant woman and the foetus

Foetus becomes viable at about 28 weeks when it weighs about 1 kg. Abortion is the termination of pregnancy before the foetus becomes viable. i.e., before it can live outside the uterine cavity. Abortion can be caused by defects in the foetus, decreased nutrition, maternal illnesses, trauma or a fall in the level of maternal hormones.

Physical hazards include damage to the foetus by X-rays in early months of pregnancy. Jumping or falling during pregnancy can cause abortion or the death of the foetus.

Many drugs have harmful effects on the pregnant mother and the foetus. They may cause deformities of the foetus or retard its growth and development.

Certain diseases are much more severe in pregnant than in non-pregnant women. For example, influenza and measles (viral diseases) give rise to severe infections in the mother. Rubella virus infection of the mother during pregnancy is known to cause deformities or death of the foetus, or abortion of the foetus. Diseases of the liver (hepatitis) may be mild in the non-pregnant but may be fatal in pregnant women, especially in later months of pregnancy.

30.2—6 Birth of the foetus

At or about the 40th week of pregnancy labour sets in. Labour is the process by which the product of conception, when it has reached full term or is nearing it, is separated from the uterus and expelled through the genital passage.

When labour begins, the uterine muscle contracts at intervals to push the foetus down genital passage.

The cervix becomes soft and it dilates. After some hours the vulva also dilates with the descent of the foetus. The frequency of the uterine contraction as well as the strength of contractions increase. The foetus is eventually expelled. Generally, the head is delivered first followed by the shoulders, then the body and finally the legs. At this stage the umbilical cord is tied and cut.

Labour continues until the placenta gets detached from the uterine wall and is also expelled. With the expulsion of the placenta, labour is complete.

In modern times surgery has helped to save many lives. The surgeon may assist the delivery if there are complications in order to save the mother or the foetus or to prevent any ill effects on either.

30.2—7 New born baby

The new born has a sudden change of environment and must be protected. After birth a healthy new born infant cries immediately and shows brisk movements of hands and feet.

The new born is very susceptible to changes in temperature and infections tend to be more severe.

The most dramatic change in the new born is that of respiration. The infant cries and the lungs expand; pulmonary respiration starts. The new born now derives oxygen from the air and not from the maternal circulation as in intra-uterine life.

Umbilical cord shrinks and shrivels and falls off later. Nutrition is now supplied orally. The best form of nutrition for the new born infant is the milk from the mother's breast.

30.3 Infancy, childhood and adolescence

30.3—1 Infancy and childhood

Infancy is that period of childhood which extends from birth to the age of one year. In this period, the child depends on someone for all its needs.

During the first three months of its life, the infant sleeps almost throughout the time, gets startled by noise or sudden movements and cries when hungry or disturbed.

During the next three months, the infant learns to recognise the mother and makes cooing and babbling sounds, takes notice of people around and occasionally smiles. Lying on the stomach, it can raise its head. When supported, it can hold its head erect and steady. The first teeth erupt.

By nine months of age, the infant crawls on four limbs and can sit erect. It can transfer objects from one hand to the other. It responds to its own name. Generally eight teeth have erupted by this time.

At one year of age the infant can stand and walk on its own, can speak simple words, play simple games and shows preference for some food and resents others.

By about one and a half years of age the child begins to understand words and simple sentences, enjoys playing alone and walking. Indulging in a variety of activities it can run for short distances and attempts climbing.

At two years of age the child may express urge to go to the toilet, attempts to put on his clothes and can now run and climb. He plays more complicated games. His vocabulary is sufficient to make demands, to express joy and anger. He understands the relationship of his parents, brothers and sisters.

At birth the infant is completely dependent on someone for all its needs—nutrition, bath, changing clothes, protection from injury, etc.

At first only breast milk is given to the infant. By three months some artificial foods, e.g milk and cereals, are given.

By six months there is a changeover to other sources of food such as cereals and fruits. Milk and fruit juices form the bulk of the diet. Soft adult diet is introduced at this stage.

By one year the infant should be having almost all food items used at home, e.g., chapati, rice, dal, etc. By this time milk is only of secondary importance in the infant's diet. However, the quantity is less and the intervals between meals are short.

HAZARDS OF INFANCY AND EARLY CHILDHOOD

Infants and children up to the age of five years face may hazards.

Malnutrition slows down the mental and physical growth of the infant and children. Malnutrition is a major problem in developing countries.

Infections are more frequent and often more severe in infants than in adults. Diphtheria, whooping cough and poliomyelitis affect infants and children more frequently, but are preventable by vaccination. Measles, chicken-pox, diarrhoea and upper respiratory tract infections are also responsible for illnesses in children.

Infants tolerate extremes of temperature very badly, especially cold. Injuries due to fall are also more common among infants and children.

As the child grows he learns to avoid dangers His vocabulary increases rapidly as he enters school. His ability to do some things for himself and his power of understanding increase During the period from three to nine years, growth in height is slow but the child gains weight in a regular manner. Sex consciousness is not very pronounced.

30.3—2 Puberty

Puberty is that phase of life when maturation of the reproductive organs takes place along with the appearance of secondary sex characteristics Puberty occurs around the age of 10-14 years. It ends with the first menstrual cycle in females. In males, it ends with spermatogenesis but the demarcation is not clear. Adolescence begins at the end of puberty.

There are some changes during puberty which are common to both males and females. There is sudden spurt in physical growth. The public and axillary hair: begin to grow Psychological and emotional changes take place. There is a feeling of clumsiness Both boys and girls become more conscious of the opposite sex.

In females, the female sex hormones, oestrogen and progesterone, begin to be produced. Deposition of fat begins which gives the rounded curves to the body. The uterus and ovaries enlarge. There is growth of the breast around the nipple The first menstrual cycle occurs between the age of 13-15 years.

In males, the male hormones, androgens, are produced Shoulders become broader than the hips The testes and associated male reproductive organs enlarge in size. Spermatogenesis begins. Occasional erections of penis and emission of seminal fluid occur. The voice becomes thick and coarse and acquires the male character.

30.3—3 Adolescence

Adolescence is the period from puberty to maturity. During adolescence the changes which started in puberty are completed.

At first, the menstrual cycle may not be accompanied by ovulation and may not be regular. During adolescence ovulation sets in with regular menstrual cycles. Further growth of the breast occurs.

The males also undergo changes in adolescence. Growth continues and muscle bulk increases. The hair growth on the face increases. Hair growth takes place on the chest

Both sexes are very inquisitive during puberty and adolescence because at first they are not very sure of what changes are taking place in their bodies. The psychological and emotional conflicts of puberty are now slowly resolved. Adolescence ends at about 18 years, when the individual is considered mature and is now an adult.

30.4 Trends in world population

A mere collection of a large number of people is not a population. Population always consists of a single species having a definite period of existence and well-defined rates of birth, death, sexes and age structure. Demography is defined as the statistical study of population. Demographers study birth rate, mortality, migrations, ethnic groups, marriage problems, survival time, family size, etc.

The problem of increasing human population is a recent one. Man appeared on the scene on this planet about one million years ago from hominoid apes who had evolved in Asia and Africa. The population of man continued to remain small sparsely spread over large areas of the planet. Then it posed no problem as man multiplied at a rate which was less than 1 per thousand per year. Despite increase in populations in different continents and rise and fall of civilizations, the population continued its slow growth rate because of tribal wars, famines and epidemic diseases until about ten thousand years ago when it started rising rapidly.

The population of the world was estimated to be 300 million about A.D. 1. From A.D. 1 to 1750, the population increased by 500 million representing an annual growth rate of 0.56 per thousand. During the next 50 years, from 1750 to 1800, it rose to 4.4 per thousand. By 1850, the world population shot up to about 1.3 billion and in 1900, the figure rose to 1.7 billion giving growth rates of 5.2 per thousand and 5.4 per thousand in the respective fifty year intervals. In 1950, the population was 2.5 billion, indicating an annual growth rate of 7.9 per thousand in the first half of the 20th century. During the last 25 years, the growth rate rose to 17.1 per thousand, raising the world population to 3.9 billion in 1974. At a growth rate of 19 per thousand the population will be 6.4 billion by the year 2000 (Fig. 30.3).

This sudden explosion of human population has created numerous problems which have compelled all nations and their planners to direct their efforts so that the population is maintained within reasonable limits according to the availability of resources for comfortable living of human beings.

In biological terms, if man devoted all his attention to the welfare of human species what is the population that this planet could sustain ?

Several limiting factors like food, fresh water, minerals, oxygen, living space, energy requirements and environmental pollution have been mentioned There is, however, scope for overcoming some of these limiting factors if science and technology are used in the most rational manner. Man has so far drawn mineral and food resources mostly from the top few metres of the earth and there is a great deal to explore. Man has also used the resources of plants and animals from the sea to an extremely limited extent. However, the vast

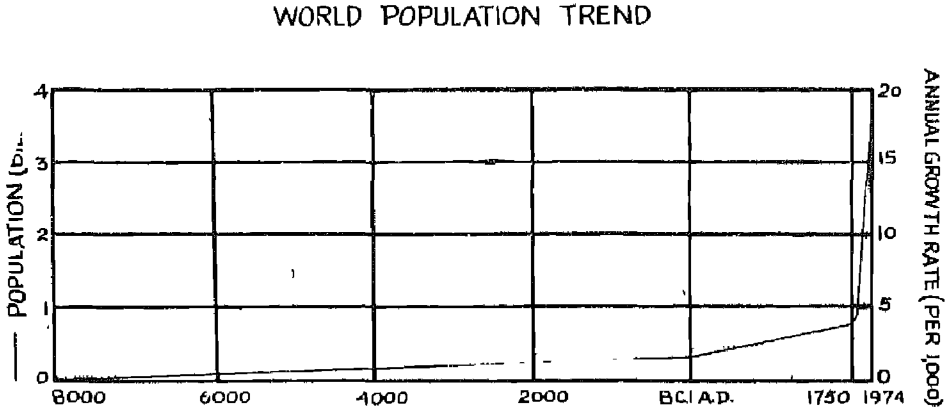


Fig. 30.3 Trend of rise in the world population

majority of the present world population cannot meet their basic needs, while a minority of 'developed' countries have so much food that they sometimes destroy crops to maintain prices. There are also eating habits which cannot be easily changed. Under such conditions the growth of population has to be kept down so that the limited materials produced can equal the demand; even families can balance their budgets and feed and clothe children if they remain small families

The important factor in determining unequal distribution of human population on this planet has been the formation and appearance of nation states. Colonization, destruction of the original populations, slave trade from Africa and contract labour of South East Asian countries have played an important role in deciding the pattern of distribution and density of human individuals in different parts of the world during the last 400 years.

There are now countries in the world with high standard of living which are considered advanced and industrialised and countries with low standard of life, less industrialised, which are considered underdeveloped countries. The population of the former is only about one billion. The remaining, more than 2½ billion as estimated in 1970, live in less developed countries of the world Nearly 70 per cent of the world population lives in less developed countries and of this nearly 75 per cent lives in Asia.

Our past experience has been that the countries having relatively higher population density had progressed industrially only when they had exploited other people through imperialism, colonialism and expansionism. The population growth rate has steadily declined as the countries became industrialised, advanced and wealthy. The rate of growth of population in poor or less developed countries, on the other hand, continues to be high between 25 to 35 per thousand as against 10 to 15 per thousand in developed countries.

30.4—1 Poverty and population

The relationship between poverty and population in any country is very complex. It involves various socio-economic factors, in addition to the birth rates and death rates in a population. These rates, in turn, are influenced by education, public health, hygiene, diseases and famine. In the pre-independent India, industry, agriculture and social development suffered severe set-back. Child death rate was extremely high, famines frequent and the average life span of the people low. Because of these reasons, the actual rate of increase of population in India, under the British rule was markedly less than that of almost any European country and was almost at the bottom of the scale of population increase in the world. Population of the Indian sub-continent in the 16th century was estimated to be 100 million. In the 1941 census, it was found to be 361 million. The population of England and Wales in 1700 was only 5 1 million. It rose to over 40 millions in a little over two centuries which is nearly double than that of Indian sub-continent rate.

Only after 1921, the population growth rate in the Indian sub-continent started increasing slowly, and more rapidly after independence. But the problems of poverty in India do not date either from 1921 or from 1951. In fact, Indian people were much poorer under the British rule and have made considerable economic advance since independence.

30.5 Population problem in India

According to the census of 1971, India's population was 548 million which was double the number recorded in 1921 (Fig. 30.4).

TABLE 30.2

Population in India in different years

Year	*Total population (in million)*
1901	238 3
1911	252.0
1921	251.2
1931	278.9
1941	318.5
1951	361.0
1961	439.1
1971	547.9

India's population in 1901 was estimated to be 238.3 million. Up to 1921 the population had increased only to 251.2 million. The death rate was over 40

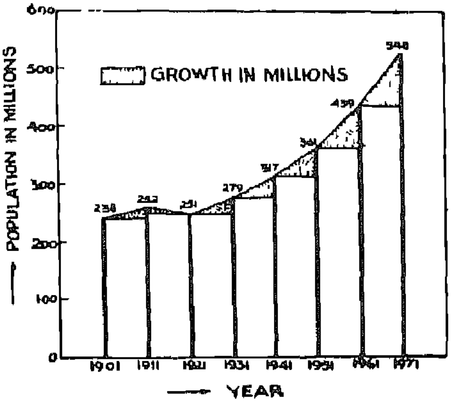


Fig. 30.4 Increase of population in India in this century

per 1,000 till 1921 and has steadily declined and is now about 16 per 1,000 for the rural population and only 10 per 1,000 in the urban areas.

The increase of population in India between 1951 and 1971 was largely due to the decline in death rate and not due to sudden increase in brith rate. The major killers like malaria, smallpox, plague and cholera were largely controlled and eliminated and health services considerably improved during this period leading to a rise in expectation of life. During 1961-71, the population increased by about 25 per thousand per year. Fourteen States (Assam, Gujarat, Haryana, Jammu and Kashmir, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland, Orissa, Rajasthan, Tripura and West Bengal) and Union Territories recorded higher growth rate than the national average. Seven States (Andhra Pradesh, Bihar, Himachal Pradesh, Karnataka, Punjab, Tamil Nadu and Uttar Pradesh) had lower growth rate than the national average.

The sex ratio in 1971 was 930 females per 1,000 males. The lowest was in Punjab with a figure of 865 females per 1,000 males. Of India's total population 42 per cent was below 15 years of age and about 6 per cent above 60 years. In 1971 about 30 per cent of India's population was literate. The percentage of literacy among males was 39.5 per cent while among females it was only 19 per cent. Kerala had the highest literacy of 60 per cent followed by Tamil Nadu and Maharashtra. The lowest literacy rate of about 19 per cent was found in Jammu and Kashmir.

The total number of illiterate among adults, in spite of the increase in literacy in younger age groups, has increased. Literacy and education are important factors in family planning programmes for control of population

The birth rate continues to be high and is around 40 per 1,000 of the population. Kerala had the lowest figure in 1971—29 8 per 1,000 and Uttar Pradesh the highest figure—46.3 per 1,000. Infant death rate continues to remain high. It was about 140 per 1,000 till a few years back. It is now showing a decline but the national average remains well over 100 per 1,000. The expectation of life has risen to over 50 years.

In 1971, India had 178 persons per square kilometre. West Bengal was the most densely populated State in India with a density of 504 persons per square kilometre. Nagaland had only 31 persons per square kilometre.

It has been estimated that if allowed to remain unchecked, India will add 1.2 million persons per month, an increase of about 14 million per year. Predictions are difficult to make but unless controlled, India's population may cross the one billion mark by the turn of the century. India accounts for nearly 15 per cent of the world population though it occupies only 2 5 per cent of the land area.

30.5—1 Indian population policy

Vigorous efforts are now being made to educate the public and take measures so that the population growth rate is reduced. It is worth noting that when a country starts on the road to development and well being of its people, a fall in the infant death rate is an important factor which in most advanced countries is less than 20 per thousand live births as against over 100 in India. A reduction in infant death rate requires welfare of the mother and the child, adequate nutrition and health care, a rising standard of living and improvement of social life. The birth rate then starts declining on its own because of the prosperity and the consciousness on the part of the people. Family planning as such looks after the health of the mother but by itself may not be adequate to control the population growth or to bring it down significantly unless vigorous disciplined efforts are made to increase industrial and agricultural production and for equitable distribution of the wealth created.

While this is being done a variety of methods of family planning have been made available. The main objective of these methods is to prevent the fertilisation of the ovum by the male sperm. The methods used are surgical, chemical, mechanical and hormonal

All these methods, however, require a certain degree of health care because no methods of family planning is without risk to the health of the persons concerned.

In the male, the main procedure used are to prevent the sperms from reaching the uterus. Research on how to alter the fertilising capacity of the male sperm, its transport from the testis to the seminal vesicles through the vas deferens and complete suppression of production of sperms is in progress. Cutting the vas deferens does not allow the sperms to reach the seminal fluid.

In the female, there are two avenues of approach. Firstly, ovulation can be suppressed by hormones. Its transport through the fallopian tubes can also be affected. Endometrium of the uterus can be influenced by mechanical and hormonal procedures so that implantation of fertilised ovum does not occur. The other approach is to use various contraceptive procedures which prevent or destroy the sperms before they enter the cervical canal.

Drugs and surgical procedures are now-a-days available to abort the newly implanted fertilised ovum. Early pregnancy can be terminated by surgical means and also aborted at this stage.

30.6 Communicable diseases of man

Human beings live in an environment which has many parasites and microorganisms. These organisms, on entering the human body, may cause diseases. Helminths, protozoa, fungi, bacteria and viruses are responsible for a large number of such diseases which are the prime cause of illness and death in this country

For infectious diseases, there is always a source of infection, which may be a patient suffering from the diseases. One who harbours these organisms, but does not suffer from the disease is called a carrier. The animal reservoirs such as the cattle and rodents, are sometimes the source for helminthic, parasitic and some viral infections.

The parasites and microorganisms must have a route of infection to reach the part of the body where they cause disease Direct contact with the patient is responsible for many skin, venereal and respiratory diseases Indirectly, infectious agents may reach a healthy person through air, water, milk, food, fomites (inanimate articles including clothing) or through the bite of animals and insects.

On reaching the body of the healthy person, there is always an incubation period during which the parasites and the microorganisms mature before manifestations of the disease appear. Finally, for its own survival, the infectious agent should have a mechanism of getting out of the body of the patient in a living form to infect other hosts.

Human beings are generally protected from the attack of these parasites and microorganisms by the intact skin and by normal secretions like the acid of the gastric juice in the stomach or the capacity of the cilia in the bronchi to capture any particles inhaled. Once the organisms have gone in, many cells of the body are brought into action for cellular defence. Simultaneously, a special class of proteins are produced in the blood which are called antibodies which specifically attack the parasites or counteract their harmful products. The host also reacts by various physiological mechanisms such as rise in temperature or diarrhoea to inactivate or eliminate the toxic products of microorganisms.

In nearly all the infections of the human body, there is a rise in body temperature, an increased rate of heart beat, increased frequency of respiration, dry tongue, poor appetite, concentration of urine and changes in white blood cells circulating in the blood.

Infections can be prevented by not allowing the parasites or microorganisms to reach the host or by increasing the resistance of the host by vaccination and immunization. Treatment is possible with specific drugs, specially against bacteria and fungi and many parasites Effective drugs for the treatment and cure of viral infections are yet to be developed.

In India the largest number of infections affect the gastro-intestinal tract.

Among the bacterial infections, cholera, gastroenteritis, typhoid fever, dysentery and tuberculosis occur only too frequently. Certain amoebae and flagellates also cause dysentery and diarrhoea. Helminths like tapeworms, hookworms and roundworms can infest the human intestine. Among the viral infections, poliomyelitis and infectious jaundice most frequently infect man through this route of infection.

These infections occur because of ingestion of contaminated food, water or milk or contact through hands. Prevention of these infections is possible by boiling the water or milk, eating freshly cooked food, preventing contamination of food and filtration and chlorination of drinking water. Vaccines to protect against typhoid, cholera and poliomyelitis are available.

Other infections which are caused by airborne bacteria reach the human body through the respiratory tract. Some of the diseases, such as sore throat, diphtheria, whooping cough and tuberculosis are caused by bacteria.

A large number of these diseases are caused by viral infections. This includes influenza, measles, chickenpox, smallpox. mumps, and meningitis. Smallpox has been eradicated in this country but chickenpox and measles continue to occur, specially during childhood.

Control of these infections is rather difficult but prevention is possible by effective vaccination. Diphtheria and whooping cough are preventable by inoculation in early childhood.

Another group of infections occurs through the bites of insects; mosquitoes and ticks are responsible for a number of protozoan, helminthic and viral infections. Malaria is caused by a protozoan. Its incidence in the country was brought down considerably under the National Malaria Eradication Programme but in recent years it has reappeared in many areas of the country.

Filaria is a helminthic infection transmitted through the bite of mosquitoes. It causes fever and repeated attack may lead to elephantiasis. Filariasis also occurs all over the country and a National Filaria Control Programme has been organized to eradicate this.

Mosquitoes transmit many viruses through their bite. Dengue occurs all over the country and is characterised by high fever, backache and joint pains lasting from 3-7 days. There are many other viral infections, some mild and others severe, which are transmitted by mosquitoes to man.

Ticks also transmit infections to man through their bite. Some are viral infections like Kyasanur Forest disease in Karnataka which is limited to a small forest area. Ticks also transmit typhus fever and relapsing fever.

Plague is a bacterial disease and is transmitted through the bite of fleas. Sandflies spread the infectious agents of sand-fly fever, Kala-azar and oriental sore.

Rabies is a viral disease and is also fatal. It occurs after bite of a mad dog or jackal or any other animal suffering from rabies infection. This is also preventable if the patient, after the bite, reports to the hospital and undergoes a full course of injections for treatment.

Many infections occur through direct contact. Venereal disease like gonorrhoea (bacterial) and syphilis (spirochaetal), trachoma (viral), scabies (mite), etc. occur due to contact infection. Tetanus is a serious, often fatal disease which is caused by the toxins produced by a bacterium which gets into a wound through contamination by dirt or soil. Tetanus is entirely preventable if the person is given immunization in early childhood by giving tetanus toxoid inoculations or is protected by anti-tetanus serum soon after injury.

Tuberculosis is a chronic disease caused by bacteria and this disease is extremely common which affects lungs, lymph nodes, bones, brain and intestines in different persons. Nearly 2 per cent of the population of this country suffers from tuberculosis. It has been estimated that there are 8 million active cases of this disease and of these nearly 2 million are infectious because they cough out a large number of tubercle bacilli in their sputum, thus creating a situation where healthy persons inhale these bacteria in air and get the disease. BCG vaccination in childhood can provide protection against tuberculosis.

Leprosy is widely prevalent in the country. Over 3 million persons are suffering from this disease and nearly 25 per cent of them are infectious for healthy persons. The disease is more prevalent in southern and eastern parts of India. Nearly 372 million of our population is exposed to the risk of getting this disease. Control measures for leprosy are difficult. Cases have to be detected, treated and properly rehabilitated.

National programmes to eradicate and control some of the major communicable diseases have been in operation. National Smallpox Eradication Programme has succeeded and smallpox does not occur in the country any more although strict watch will have to be kept for the next few years. The National Malaria Eradication Programme very nearly succeeded but for some recent set backs.

The National Leprosy Control Programme has made headway and large number of service and treatment centres have been set up for this purpose. The National Tuberculosis Control Programme has an integrated approach including BCG vaccination, detection and treatment of cases and isolation of tubercular persons through education, proper housing and sanitorium treatment.

The National Cholera Control Programme is based on improvement in environmental sanitation, availability of safe drinking water and proper disposal of human excreta. Cholera vaccine is available but offers protection for a short period only. The National Filaria Programme is based on reduction of the mosquito population by antilarval measures and by reducing the reservoir of infection by treatment of affected persons.

Trachoma is responsible for severe diseases of the eye and is being controlled by providing ointment containing antibiotics through the rural health services.

Venereal diseases are more of a social problem and require education and social efforts for their control in the country.

30.7 Nutritional disorders of man

Adequate nutrition is essential for maintaining a healthy state of the human body. Balanced requirements of calories, proteins, carbohydrates, fats, vitamins, minerals and trace elements for the proper growth and maintenance of human body are indeed well known. It is an unfortunate fact that a vast majority of the people of the world are very poor and they are unable to receive proper or balanced nutrition. It has been estimated that over one-third of world's population receives less than 2,000 calories per head per day. Deficiency of one or the other essential requirements in food leads to poor health, an increased susceptibility to diseases and a reduction in the life span.

Quantitative deficiency of food leads to under-nutrition and may lead to starvation. This arises at the time of large scale famines when there is not enough food to eat. Among individuals, under-nutrition or starvation may be seen in severe diseases of the digestive system which prevents intake or absorption of food and also among patients with severe infections of liver or kidney failure when normal metabolism becomes disturbed.

Inadequate diet results in the loss of weight and a person is considered undergoing starvation if the body weight is reduced to 75 per cent or more of the normal.

During times of famine, a patient's desire for food is not a guide to what he can digest. Small amounts of skimmed milk given as frequent feeds is the best way of making him recover.

Qualitative deficiencies also occur when food is deficient in the essential nutrients, but they may also be due to wrong food habits.

30.7—1 Protein caloric malnutrition

Protein calorie malnutrition (PCM) can cause several disorders. In the majority of the children, PCM leads to their remaining underweight and they are susceptible to infections of respiratory and gastro-intestinal systems. In some children, it may cause dwarfing with low weight and short stature Such children are also more susceptible to infections than the normal ones.

Marasmus (Fig 30 5) is a severe wasting disease of childhood due to grossly inadequate diet seen among infants of one year of age. Early and abrupt weaning due to poverty, subsequent feeding with diluted milk, repeated infections lead to growth retardation and wasting of muscles reducing the child to skin and bones.

Kwashiorkor due to PCM occurs among children of 1—4 years age. After

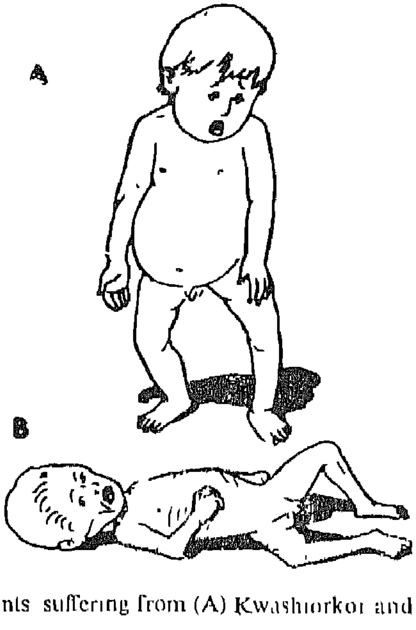


Fig 30.5 Infants suffering from (A) Kwashiorkor and (B) Marasmus

weaning they are able to get a diet mainly consisting of carbohydrate with only a low protein content Infections like those of the gastro-intestinal tract and measles may contribute to precipitate the disease A child suffering from Kwashiorkor shows swelling of feet, wasting of muscles and changes in hair. Mental changes, skin changes, markedly enlarged liver and anaemia are also seen among such children.

About one per cent of pre-school children in India suffer from kwashiorkor, marasmus is twice more common than this disease. Kwashiorkor is entirely preventable through intake of adequate diet and education of parents about dietary habits.

30 7—2 Mineral deficiency diseases

Many elements occur in the body which are essential for metabolism and physiological functions. They include sodium, chlorine, calcium, sulphur, iron, iodine, fluorine and zinc.

CALCIUM

Milk is a rich source for calcium and half a litre cow's milk contains 0.6 gm of calcium. Vegetables, cereal grains and drinking water also provide calcium to human beings. Increased demands for calcium are made during pregnancy and lactation. Inadequate intake of vitamin D leads to disturbed metabolism of calcium.

IODINE

Iodine is widely distributed in food and water. It is an essential element in the functioning of the thyroid gland and its hormones Lack of iodine results in enlargement of the thyroid which is known as *goitre*. In India about 9 million people are affected and another 45 million face the risk of getting goitre.

Goitre occurs extensively in the sub-Himalayan region from Kashmir to Arunachal and the highest prevalence has been noted among young boys and girls. Goitre leads to high incidence of *cretinism* which is characterised by physical and mental changes and disorders of the nervous system. One of the successful ways to prevent goitre is to add one part of iodine to 10-20 thousand parts of common salt.

FLUORINE

The commonest source of fluorine are drinking water (specially hard water), sea fish and tea. Fluorine is present in human bones There is a greater incidence of teeth decay (dental caries) if the amount of fluorine in drinking water is less than 0.5 part per million parts.

IRON AND OTHER ELEMENTS

Iron is present in adequate amounts in meat, fruits and green leafy vegetables. Formation of blood cells in the bone marrow requires iron, traces of copper and cobalt, vitamin B_{12}, folic acid, ascorbic acid, pyridoxine and proteins. Deficiency of iron causes *anaemia.*

Depletion of sodium and potassium are associated with disturbances of water and electrolyte metabolism of the body. Traces of copper, magnesium and cobalt are essential for formation of normal red blood cells.

30.7—3 Vitamin deficiency

Human body requires vitamins for its normal metabolism. It cannot synthesise them in adequate quantities for this purpose. An external source through diet, therefore, becomes essential. Deficiencies of five major vitamins are known to occur in man, viz., vitamins A, B-complex, C, D and K. Among these vitamins A, D and K are fat soluble. Vitamins C and B-complex are water soluble. Fat soluble vitamins are not available if there is no fat in the diet. Anti-vitamins are known to occur in raw fish and certain synthetic drugs. Some vitamins are present in food as precursors like carotene for vitamin A. The bacteria in the intestine synthesise certain vitamins like vitamin B-complex and vitmain K but they also reduce the amount of other vitamins. Vitamin D may not be required if skin is adequately exposed to the sun.

Vitamin A is found in milk, liver, fish and is widely distributed in plants and fruits. Vitamin A deficiency leads to *night blindness*—involvement of conjunctiva which becomes dry, thickened and pigmented, later leading to ulcers of the cornea which may cause total blindness. These diseases are entirely preventable if adequate amounts of vitamin A are available in the diet, viz , 300 to 600 mg per day for infants and children, 750 mg for adults and 1200 mg for lactating mothers.

Vitamin D deficiency causes *rickets* in infants and children, and *osteoma-*

lacia in adults. Both these conditions are frequently reported in India. Deficiency of vitamin D may occur not only because of inadequate amounts in the diet, but also due to poor housing and inadequate exposure to sunlight, which is plentiful in India. The vitamin D deficiency is usually associated with inadequate intake of calcium.

Vitamin K is essential for the formation of prothrombin which is required for the normal clotting of blood. Vitamin K is present in dark green vegetables like spinach. Normally occurring bacteria in the intestine can also synthesise vitamin K. Vitamin K is required in the treatment of disorders of clotting of blood.

Vitamin C or ascorbic acid is present in citrus fruits and vegetables. Deficiency of vitamin C in the diet leads to *scurvy* with bleeding gums and haemorrhages in the skin. Scurvy used to occur among sailors on long voyages and is not seen now-a-days. Other minor ailments like delay in healing of wounds, loss of appetite, tender joints have also been listed as caused by relatively minor deficiency of vitamin C. Total requirement of vitamin C for an adult is 30 mg daily. It has been claimed that ascorbic acid in large doses can help overcome common cold.

Vitamin B-complex consists of a group of water-soluble vitamins. Though not related chemically, they are grouped together because they are essentially parts of specific enzyme systems on which cell metabolism depends.

Thiamine (vitamin B_1) deficiency causes *beri-beri* which leads to swelling of the legs, the face and the involvement of peripheral nerves.

Niacin is an essential part of two important pyrimidine nucleotides. Its deficiency causes *pellagra* among people who live mainly on maize. Sunburn-like patches on limbs and disturbances of nervous system occur in this disease.

Riboflavin is required in the diet. Its deficiency causes small ulcers in the mouth.

Vitamin B_6 consists of three closely related chemical compounds and acts as a co-enzyme. Vitamin B_6 deficiency is rare in man.

Vitamin B_{12} is found in foodstuffs of animal origin and in microorganisms—bacteria and moulds (fungi)—and 2 mg of this is required per day. The body can store this vitamin and the effects of the deficiency are, therefore, seen much later. Vitamin B_{12} is essential for the formation of blood. Its deficiency causes anaemia and degeneration in the spinal cord.

Folic acid is found in dark green vegetables, liver and kidney Other green vegetables, pulses, nuts and some sea foods are also good sources of folic acid. Deficiency of folic acid causes anaemia and atrophy in parts of the gastro intestinal tract

It should be noted that the deficiency of an essential nutritional requirement at first leads to adaptation by the body to the low intake, for instance, by lowering the excretion through urine. In the second stage, biochemical changes occur but no disease is noticeable In the third stage, the disease manifests itself.

30.7—4 Over-eating

Obesity is the abnormal accumulation of fat throughout the body. About 10-15 per cent of adolescents in affluent countries are over-weight and over 90 per cent of them are over-weight due to over-eating. Genetic, environmental, hormonal and metabolic factors are also responsible for obesity Affected
m diseases of cardiovascular system. Life expec-
lequate diet and physical exercise can prevent the

ınts can cause temporary headache, nausea and
can cause increased amounts of calcium in blood,

ing water causes chronic fluorine poisoning.
s of Andhra Pradesh, Punjab and Karnataka.
d from Tamil Nadu, Haryana, Rajasthan, Uttar
measures require supply of drinking water free
filtration methods have been devised which can
inking water.

mption of large quantities of *Lathyrus sativus*
over 30 per cent of *L. sativus* taken for more
disease as shown by the paralysis of lower
certain parts of Madhya Pradesh, Uttar Pradesh

EXERCISES

1. List the main parts of the male reproductive system.
2. Name the main parts of the female reproductive system.
3. Describe the different stages of the female menstrual cycle.
4. Describe the formation of functional sperms.
5. What are the changes that occur in the mother's reproductive system soon after fertilisation ?
6. What are the main changes that occur in the mother's body during pregnancy ?
7. What are the main hazards to the foetus ?
8. Enumerate the different stages of development of the human foetus.
9. Enumerate the different stages of anatomical and functional development of an infant.
10. At what stage does the infant:
    - (i) turn while lying ?
    - (ii) sit erect ?
    - (iii) stand on its own ?
    - (iv) erupt the first pair of teeth ?
    - (v) speak simple words ?
11. Mention the types of food given to infants at different ages up to two years.
12. What changes occur during adolescence in male and in female ?
13. What are the parameters of the science of demography ?
14. List the possible limiting factors to human population on this planet.
15. What is the relationship between poverty and population ?
16. What are the reasons for increase in population growth in India after 1951 ?
17. Describe the measures by which birth rates can be lowered.
18. How is the body generally protected from the attack of parasites and micro-organisms ?
19. Mention some of the bacterial, viral, protozoal and helminthic diseases which affect man through the gastro-intestinal tract. How can they be prevented ?
20. Write a short note on diseases caused by bites.

21. Write a short note on national disease control and eradication programmes.
22. Write a short note on protein calorie malnutrition (PCM).
23. Write short notes on the daily requirements of (i) Calcium, (ii) Iron and (iii) Iodine in human diet. How would you prevent deficiency of each ?
24. Give the sources and deficiency diseases of the following:
    (i) Fluorine, (ii) Vitamin A, (iii) Vitamin C, (iv) Folic Acid (v) Vitamin B_{12}, (vi) Vitamin D.
25 What are (a) Goitre, and (b) Lathyrism ?

Chapter 31

Metals and Metallurgical Processes

Metals are extremely important for the modern civilisation, as we can see from the common use of iron, aluminium, copper, zinc and their alloys. Alloys are generally formed by mixing various metals in the molten state and then cooling to room temperature. They have unique properties which need not be similar to those of their components. Indeed, we use alloys these days more than pure metals. For example, steel, brass and bronze are all alloys.

In earlier classes we have studied some general properties of metals. For example, all metals show the following properties to some extent which, distinguish them from non-metals.

1. Metals show a bright *metallic* lustre.
2. Metals are good conductors of heat and electricity.
3. Metals are *malleable*, i e. they can be beaten into sheets.
4. Matals are *ductile*, i.e. they can be drawn into wires.
5 Metals generally react with acids to form salts with the evolution of hydrogen. In these salts, the metals commonly constitute the cations.

31.1 What is the position of metals in the periodic table ?

About eighty per cent of the known elements are metals. They are all clustered on the left side and in the centre of the periodic table. The elements on the right side of the periodic table are non-metals and inert gases (Fig. 31.1). The metallic properties are most pronounced in the exterme left. Some elements lying between metals and non-metals exhibit intermediate properties. These elements occupy a diagonal region extending from top centre to bottom

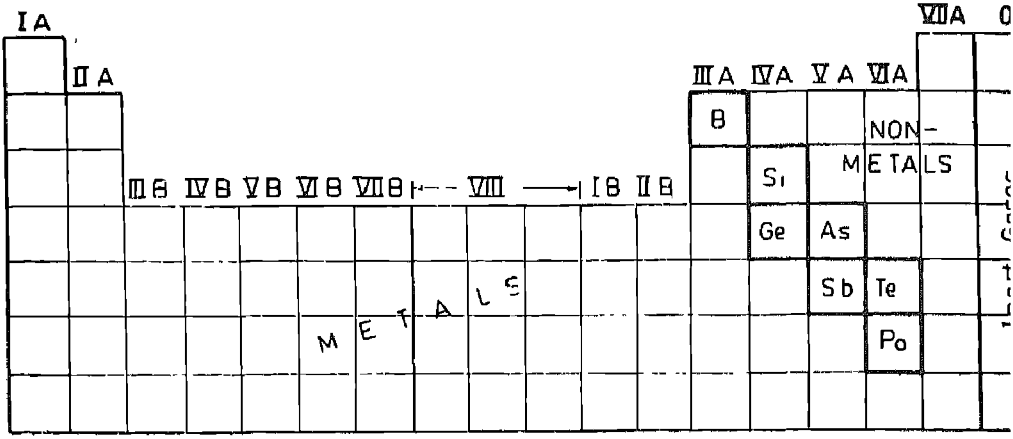


Fig 31.1 Position of metals in the periodic table

right corner of the periodic table (Fig. 31.1). They are referred to as *metalloids*. These include boron, silicon, germanium, arsenic, antimony, tellurium and polonium.

31.2 What are some simple chemical properties of metals ?

(a) *Reaction with air.* Sodium when kept in air reacts readily with oxygen to give sodium oxide (Na_2O). Magnesium burns in air on heating to form magnesium oxide, whereas iron and copper on prolonged heating in air give oxides but they do not burn

(b) *Reaction with hydrogen:* When hydrogen is passed over heated sodium and calcium, sodium hydride (NaH) and calcium hydride (CaH_2) are formed Magnesium hydride and copper hydride are formed only with difficulty They are not stable

(c) *Reaction with chorine.* All these metals react with chlorine to give chlorides Sodium is the most reactive and the reactivity of these metals varies in the order Na> Mg> Fe> Cu.

$$2Na + Cl_2 \rightarrow 2NaCl$$
$$Mg + Cl_2 \rightarrow MgCl_2$$
$$2Fe + 3Cl_2 \rightarrow 2FeCl_3$$
$$Cu + Cl_2 \rightarrow CuCl_2$$

(d) *Reaction with sulphur:* When a mixture of any of these metals with sulphur is heated, sulphides are formed.

$$2Na + S \rightarrow Na_2S$$
$$Zn + S \rightarrow ZnS$$
$$4Al + 6S \rightarrow 2Al_2S_3$$
$$4Fe + 6S \rightarrow 2Fe_2S_3$$

In these reactions, the reactivity is found to be in the order Na > Al > Zn > Fe.

(e) *Reaction with water.* Sodium reacts vigorously with water at room temperature liberating hydrogen.

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

When steam is passed over heated magnesium, iron or zinc, then hydrogen is also liberated

$$Mg + H_2O \rightarrow MgO + H_2$$
$$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$$
$$Zn + H_2O \rightarrow ZnO + H_2$$

The reactivity is in the order Na > Mg > Zn > Fe.

(f) *Reaction with acids:* We have already studied that zinc and iron react with dilute hydrochloric acid or sulphuric acid to give hydrogen. Copper does not do so. We will read about the reason in higher classes.

(g) *Displacement of metals from their solutions*: Concentrated solution of copper sulphate is taken in three test tubes. Strips of zinc and iron, and a platinum wire, respectively, are dipped in the test tubes. It is found that after some time copper is deposited on the zinc strip and at the same time the colour of the solution gradually fades The following reaction takes place

$$Zn + Cu^{2+} \rightarrow Cu + Zn^{2+}$$

Here, zinc atom gives two electrons to Cu^{2+} ion and gets oxidised to zinc ion (Zn^{2+}) and goes into solution A Cu^{2+} ion takes up two electrons from zinc atom and gets reduced to copper which is deposited on the zinc strip.

Similar is the reaction with iron:

$$Fe + Cu^{2+} \rightarrow Cu + Fe^{2+}$$

Iron is oxidised to iron (Fe^{2+}) ion and goes into the solution and copper is reduced and deposited as copper metal on the iron strip.

There is no reaction in the case of platinum wire. If a strip of zinc is dipped in a solution of lead acetate, it is observed that lead is deposited on the strip.

$$Zn + Pb^{2+} \rightarrow Pb + Zn^{2+}$$

This shows that zinc is oxidised and lead is reduced.

The above observations help in comparing the reactivities of these metals.

Similar conclusions can be arrived at by studying the reactions between a metal oxide and free metals For example, let us study the reactions between (i) cupric oxide and magnesium, and (ii) iron oxide and aluminium.

When a mixture of cupric oxide and magnesium powder is heated, white magnesium oxide is formed.

$$CuO + Mg \rightarrow MgO + Cu$$

Our knowledge of oxidation-reduction reactions shows that copper oxide is reduced and magnesium is oxidised.

Similarly, when a mixture of aluminium powder and ferric oxide is heated, we observe the formation of white aluminium oxide

$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$$

Here aluminium is oxidised and ferric oxide is reduced. From all the above reactions, we can conclude that the most characteristic property of metals is their tendency to lose electrons, which differs from metal to metal. Greater the tendency of the metal to lose electron, the more reactive it is.

On experimenting with different metals and salts it was observed that the reactivity of different metals is different. Metals can be arranged according to their decreasing activity in the following order:

K, Na, Ba, Mg, Al, Zn, Fe, Ni, Sn, Pb, (H), Cu, Hg, Ag, Pt, Au.

This series is known as *activity series of metals.* Although, hydrogen is not a metal, it has been given a place in this series. The metals which are placed on the left hand side of hydrogen can displace hydrogen from acids. In addition to this, each metal can displace the metals on its rignt hand side from their salt solutions.

31.3 General Metallurgy

The less reactive metals like silver, gold and platinum are found mostly in the free or native state. The metals such as copper and aluminium are found both in the free and combined state. The natural materials in which metals or their compounds occur in the earth are called *minerals.* Those minerals from which the metals can be produced profitably are called *ores.* A large percentage of rocky material, called *gangue or matrix*, accompanies the useful metals or their compounds.

Some of the important classes of ores used in the preparation of metals are oxide ores, sulphide ores, carbonate ores and halide ores In order to produce the metal from them a number of physical as well as chemical processes are involved These depend upon the nature of the ore and the local conditions. The various processes involved in the production of the metal are collectively referred to as *metallurgy*.

The various metallurgical operations can be divided into three stages, namely

(i) preliminary treatment to separate gangue from the ore and to convert it into a form which is more suitable for subsequent processes.
(ii) conversion of the enriched ore into metal by appropriate chemical reactions; and
(iii) refining of the metal to obtain it in a pure form.

A summary of these processes is given in the chart.

An Outline of Main Metallurgical Operations

Ore

↓

Preliminary treatment involving one or more of the following processes to remove gangue (rocky material etc.) and to prepare the ore for further processing:

(i) Magnetic separation
(ii) Hydraulic washing
(iii) Froth floatation
(iv) Calcining
(v) Roasting

↓

Enriched ore containing higher concentration of the metal in a more readily extractable form

↓

Wet Process

Leaching of the ore with a suitable reagent to extract metal in the form of a soluble salt, e.g. (i) Cuprous sulphide ores are leached with dilute H_2SO_4 in the presence of atmos-

↓

Dry Process

Metals are obtained by a variety of reduction processes, e.g. (i) Iron is obtained by heating its oxide with coke.

$$2Fe_2O_3+3C \rightarrow 4Fe+3CO_2$$

pheric oxygen to give $CuSO_4$ solution (ii) Extraction of uranium with H_2SO_4 as uranyl sulphate These salts may be used as such or converted into free metal.

(ii) Chromium is obtained by reduction of its oxide with aluminium (Alumino-thermite process)

$$Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$$

(iii) Electrolytic reduction as in the production of aluminium

↓

Raw Metal

↓

Refining The metal obtained above is purified by one of the following methods:

(i) Electrolytic refining as in the case of copper and aluminium.

(ii) Distillation or sublimation as in the case of mercury and zinc, respectively

(iii) Removal of impurities by oxidation as in the removal of carbon, phosphorus, silicon, etc from pig iron.

↓

Pure Metal

31.3—1 What is the preliminary step in metallurgy?

The ore is crushed and ground The gangue is separated from the metal compound by making use of differences in their physical properties For example, some minerals may be attracted towards magnetic field (*magnetic separation*) but gangue is not This is the principle underlying the separation of chromite ($Fe(CrO_2)_2$) or pyrolusite (MnO_2) from the gangue. In other cases, like the ores of tin and lead, advantage is taken of the differences in density. The lighter gangue particles are washed away in a stream of water while the heavier minerals stay behind (*hydraulic washing*). Some of the sulphide ores have the property of adhering to air bubbles. These can be enriched by the *froth floatation* process. The powdered ore is mixed with water and pine oil and air is bubbled through it The sulphide minerals float on the surface with the froth and gangue settles at the bottom. Volatile matter, like moisture or water of crystallisation, may be removed by simple heating (*calcining*). Most sulphide ores are heated in a stream of air to convert them to oxides and to remove sulphur as sulphur dioxide (*roasting*)

The enriched ore is converted into free metal through a series of chemical reactions.

31.3-2 How is metal refined?

The metal obtained in the above step is generally not very pure and another treatment is required to purify it. For example, iron obtained from Fe_2O_3 (*pig iron*) contains a lot of carbon, silicon, phosphorus and some other impurities. These may be removed by passing air through molten iron. The impurities are converted into their oxides and removed (*oxidative refining*). The more volatile metals like mercury and zinc are purified by distillation or sublimation. Impure copper is refined by electrolysis. The block of impure copper dipping in a solution of copper sulphate serves as the anode. The cathode is made of a thin plate of pure copper. On passing electric current, copper is dissolved from the anode and deposited on the cathode The impurities collect at the bottom below the anode (*electrolytic refining*).

31.4 Aluminium

Aluminium is placed in group III-A of the periodic table. Its electronic configuration is 2 8.3.

31.4-1 What are some important properties of aluminium ?

Aluminium is a bluish white metal of low specific gravity (2.71). It is highly malleable, i.e. it can be beaten or rolled into thin sheets or foils. It is ductile and can be drawn into wires.

As stated above, aluminium is a reactive trivalent metal. It reacts with active non-metallic elements, like oxygen, halogens etc.

(i) *Action of oxygen*: When heated to 800°C or higher, aluminium burns with a brilliant white light to form aluminium oxide. The reaction is very strongly exothermic.

$$4Al + 3O_2 \rightarrow 2Al_2O_3 + \text{heat}$$

Even at room temperature, aluminium reacts with oxygen to form a thin but tough layer of aluminium oxide on the surface. This layer protects aluminium from further corrosion

(ii) *Action of hologens*: On heating, aluminium reacts with chlorine to form aluminium chloride.

$$2Al + 3Cl_2 \rightarrow 2AlCl_3$$

This reaction is used for the manufacture of anhydrous aluminium chloride, which is used as a catalyst in many chemical industries.

(iii) *Action of acids*: Aluminium reacts with acids to form salts and hydrogen gas.

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$$
$$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$$

(iv) *Action of alkalies*: Aluminium is attacked by strong alkalies at high temperature with the formation of aluminates and evolution of hydrogen gas.

$$2NaOH + 2Al + 2H_2O \rightarrow \underset{\text{sodium aluminate}}{2NaAlO_2} + 3H_2$$

(v) *Action of water*: Ordinary aluminium strips or vessels are not attacked by water because of protection by the layer of aluminium oxide. In the absence of such a layer aluminium reacts with water even at room temperature.

$$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2$$

31 4—2 What are the properties of aluminium oxide ?

Aluminium oxide reacts with both acids as well as alkalies to form two different types of salts. In one case aluminium is the cation and in the other it is a part of the anion.

$$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$$
$$Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$$

Note that in the reaction with acid, aluminium oxide behaves as a *basic* oxide which neutralises acid to form salt and water. On the other hand, in the reaction with alkali, it behaves as an *acidic* oxide and produces a salt and water. Therefore, aluminium oxide is referred to as an *amphoteric oxide.*

31.4—3 What are the uses of some aluminium salts ?

Ordinary alum (also known as potash alum), is a double salt of potassium sulphate and aluminium sulphate, $K_2SO_4.Al_2(SO_4)_3.24H_2O$. It is used in purification of water, tanning of leather and as a mordant in dyeing. Anhydrous aluminium chloride is used as a catalyst in a number of chemical industries.

Alum is a general term used for double sulphates of a monovalent and a trivalent metal. They all contain twenty four molecules of water of crystallisation and have the same crystal shape. For example, $K_2SO_4.Cr_2(SO_4)_3.24H_2O$ and $K_2SO_4.Fe_2(SO_4)_3.24H_2O$ are called chrome alum and iron alum, respectively.

31.4—4 What are some important alloys of aluminium ?

Pure aluminium metal finds limited use as aluminium wires and vessels, etc. However, its alloys are used very widely. For example, its alloy with 10-30% magnesium, namely *magnalium*, is light and hard and can be worked on lathes, etc. to make light instruments. Another important alloy of aluminium is *duralumin*. It contains 4% copper, 0.5% each of magnesium and manganese and the rest aluminium. It compares with steel in strength and is only half as heavy. It is used in making aeroplane parts, pressure cookers, etc.

31.5 Iron

Iron is one of the most useful metals and is extracted on very large scale from its ores, mainly haematite (Fe_2O_3) and magnetite (Fe_3O_4 or $Fe_2O_3.FeO$). Our country is very rich in both these ores. It is not surprising, therefore, that metallurgy of iron was known to ancient Indians. Indeed, at that time we were ahead of the rest of the world in this respect. Some fine pieces of iron articles built centuries ago in our country are still found in good shape. For example, we have the famous wrought iron pillar of Delhi (built in 4th century A.D), the huge iron girders of Puri, the ornamental gates of Somnath and the approximately 13.1 metres tall Dhar pillar in Malva.

Iron is extracted from its ores by reduction with coke in a blast furnace at high temperatures, as we have read in previous classes. The chemical reactions which take place inside the blast furnace may be represented by the following equations.

$$\begin{array}{llllllll} 2C & + & O_2 & \rightarrow & 2CO & + & \text{heat} \\ 3Fe_2O_3 & + & CO & \rightarrow & 2Fe_3O_4 & + & CO_2 \\ Fe_3O_4 & + & CO & \rightarrow & 3FeO & + & CO_2 \\ FeO & + & CO & \rightarrow & Fe & + & CO_2 \end{array}$$

Iron obtained from blast furnance (pig iron) has considerable dissolved carbon, and other elements like silicon, phosphorus and manganese These are subsequently removed by burning in limited supply of air passed through molten metal to give wrought iron. Both pig iron and wrought iron may be subsequently converted into steel having the desired amount of carbon.

31.5—1 What are some of the important properties of iron ?

Ordinarily iron appears brown because it is covered with rust. When freshly cut or rubbed with sand paper, it is dark gray Wrought iron does not rust so easily but other varieties of iron do. Rusting can be prevented by coating the surface with zinc by dipping in molten zinc. This process is called *galvanising* Many objects are made from galvanised iron for daily use Rusting is also prevented by dipping in molten tin A more handy or household method of preventing rusting is by applying grease, fat or paint All these have the common function of preventing air and moisture from coming into contact with iron

Pure iron is comparatively soft However, metal of varying hardness can be obtained by mixing various amounts of carbon in molten iron. Such an iron-carbon alloy is called *steel*. The percentage of carbon in steel of different hardness is shown below:

Mild steel	0 05—0.2%
Medium steel	: 0 2—0.6%
Hard steel	: 0.6—1.5%

Mild steel is malleable and ductile and is used to prepare sheets, wires, etc Medium steel is harder and is used for the manufacture of rails, wheels, building meterials, etc. Hard steel is mainly used for tool making The degree of hardness can be further adjusted by heat-treatment, or *tempering*, in which the article is heated and cooled at controlled rates. The properties of steel can also be modified in the desired manner by alloying it with other metals to give *alloy steels*. For example, stainless steel contains iron, carbon, chromium (12-14%) and nickel (0.7%).

Iron and steel are used to a very large extent in modern technology. Indeed, the amount of iron produced and consumed in any country can be taken as an index of the state of development of the country. In this respect, we are progressing fairly rapidly now. In India the annual production of steel was 8.043 million tonnes in 1982.

EXERCISES

1. Mention five properties which distinguish metals from non-metals.
2. Give six chemical properties (with equations) of metals.

3. Which metal in each of the following pairs is more reactive ?
   - (i) Zinc and copper
   - (ii) Copper and iron
   - (iii) Lead and zinc

   Explain with the help of chemical equations.
4. What do you understand by the terms mineral, ore and gangue ?
5. Mention different methods of preliminary treatment of the ores.
6. Write equations for the reaction of aluminium with acids, alkalies and water.
7. Explain the following terms :
   - (i) magnalium
   - (ii) duralumin
   - (iii) stainless steel
   - (iv) galvanisation
   - (v) tempering of steel
   - (vi) refining of metals
8. What is an amphoteric oxide ? Give an example and explain with the help of suitable reactions.

Chapter 32

Some Applications of Science

Ever since the beginning of civilization, man has been striving at making life easier and comfortable Observations of the various happenings around us by the scientists have greatly helped in understanding the behaviour of both inanimate and animate objects in terms of some of the basic concepts such as energy, radiation, kinetic theory of molecules, wave motion, chemical equilibrium, reaction kinetics, irritability, locomotion, reproduction, growth, and so forth We now know the behaviour of a moving object in terms of its velocity, the behaviour of a chemical reaction at the beginning and at the completion stage, the manner in which sound waves behave under different circumstances. We also now understand the dynamics of locomotion, the manner in which the living things respond to internal as well as external stimuli. We also understand the unique manner in which all the living things grow and reproduce. Acquisition of all this knowledge has helped the scientists in producing new types of materials and in developing sophisticated machines. Such applications have been possible by making use of the well understood physico-chemical principles which govern the behaviour of the living and the non-living substances and allow changes in a desired manner. These beneficial applications of science for the betterment of mankind have come to be known as technology. Our life is influenced by technology in several ways. Apart from the large-scale applications in industry, scientific principles have also been profitably applied to agriculture, sericulture, poultry, animal husbandry, etc. In this chapter, we will study how some of these applications play an important part in our day-to-day life.

32.1 Physics in communication

32.1—1 Conversion of A.C. into D.C.—rectification

In our daily life the use of electricity is increasing day by day. In general, the electrical energy is used in the form of A.C However, there are many applications, such as electromagnets and battery chargers, where one needs D.C. in which case one can either use dry cells, as in a portable radio, or convert the available A.C. supply into the desired D.C. voltage. This process is called *rectification*. One of the important components of such a conversion is a rectifier which is also known as a diode.

A diode is made of a small piece of the element silicon, sealed in a glass or plastic body with two wires coming out at the two ends as shown in Fig. 32.1. The symbol used for a diode is also shown along with it. The body is marked at one end with a coloured stripe or a coloured dot.

The action of a diode in the rectification circuit is similar to a football pump valve which allows air to flow from the pump to the football bladder but does not allow it to come back The diode allows the current to flow from the unmarked end to the marked end. However, it will not allow the current to flow in the reverse direction even if the voltage at the marked end is higher than that at the other. This property of the diode is made use of for converting A.C. voltage into D.C. voltage. The flow of a current in only one direction in a circuit is very similar to the flow of a current from a dry cell which we know is a direct current (D.C.).

This process of rectification is made use of to provide D C power in all radios, battery eliminators and amplifiers working on A.C.

32.1—2 Amplification

It is our everyday experience that we can make ourselves heard by others in a room without much effort. On the other hand, a teacher will have to speak

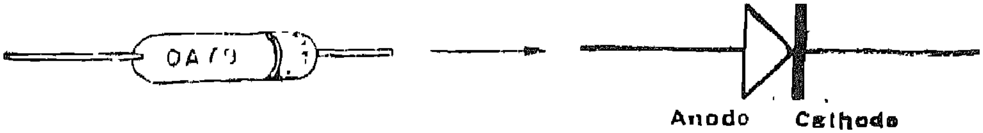


Fig. 32.1 A diode and its symbol

loudly so that everyone present in a bigger classroom can hear him. However, in the school assembly hall where all the students assemble, the speaker will have to shout to make himself heard by everyone. In a public meeting, the speaker, even if he shouts at the top of his voice, would be heard only by a few sitting near him. We also know that louder we shout, the more energy we spend. It is, therefore, necessary that to make him heard by everyone, we make use of some means to increase the loudness. That is, the method should increase the sound energy. many times compared to what the speaker can normally deliver in his speech. This process of increasing the sound level is called *amplification* and the instruments which use this principle are called *amplifiers*.

A transistor is a small device made of the element silicon and sometimes germanium. It has three wires as shown in Fig. 32 2, along with the symbol used to represent it. Its interesting property is that if small energy is given to a particular wire of the transistor, the energy appears in an amplified form at the remaining two. The source of this additional energy is the battery to which the device is connected. It is, therefore, convenient to use transistors as amplifying units in most applications.

Public address amplifier

A public address amplifier or P.A. amplifier , as it is called, is an electro-

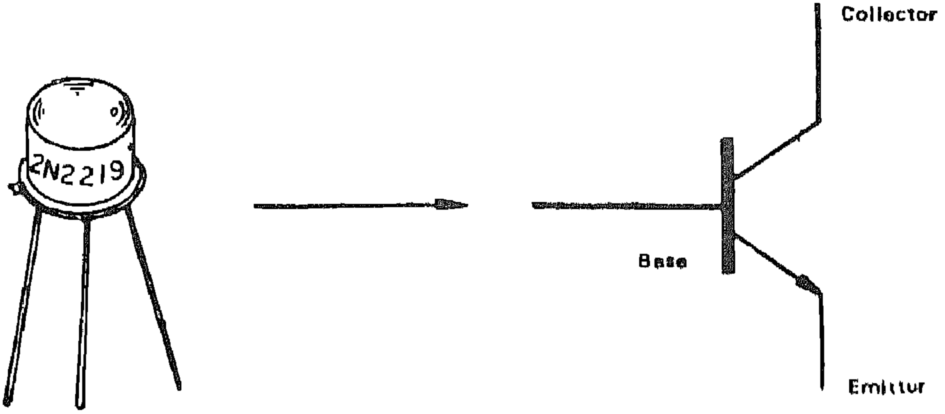


Fig. 32.2 A transistor and its symbol

nic device which amplifies our voice energy and thus helps in making us heard over large areas. Fig. 32.3 shows the different parts of a simple public address amplifier system.

When a person speaks in front of a microphone, it converts the sound into electrical energy. The stylus is a small needle with an extremely fine point which moves in the grooves of a record This groove has fine marks corresponding to sound waves which move the stylus back and forth. Inside the pick-up, these tiny movements are converted into electrical energy. These very small electrical changes (about 10^{-3} V) are given to an amplifier consisting of a chain of transistors so that we get the increased energy that we want. This electrical energy is given to the loud-speakers. The loud-speakers change the electrical energy into sound.

The sound level obtained from the P.A. amplifier should be adjustable so that the audience can hear the speech clearly. It should not be too low as not to be heard by people behind, nor should it be too high to make persons nearby uncomfortable. It is, therefore, necessary to control the sound level. This is achieved by using a control arrangement called volume control in P.A. amplifiers.

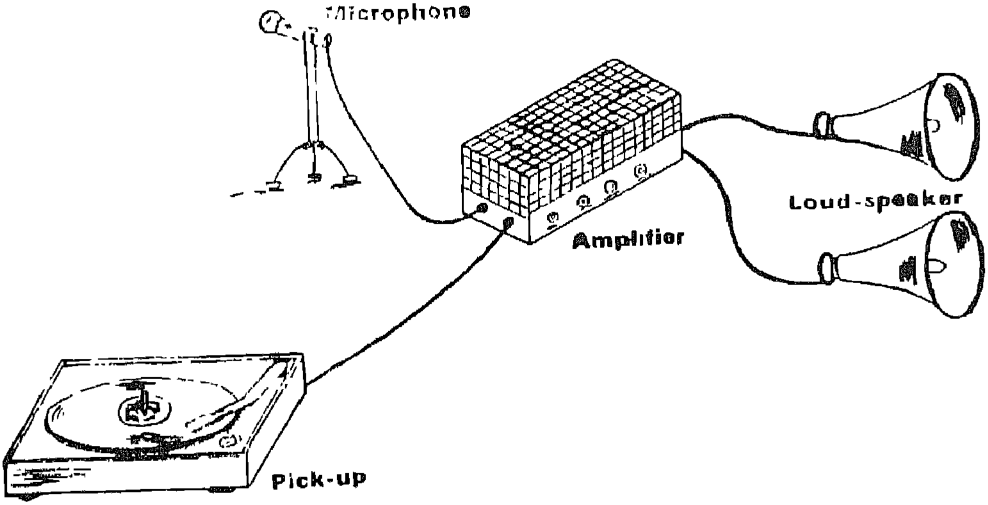


Fig. 32 3 Public address amplifier system

These amplifiers are designed either to work on A.C. voltage (230 V) or on car batteries.

32.1—3 Radio station (Transmitter)

Earlier, we found that with the help of an amplifier we can send our voice to a maximum distance of, say, one kilometre Now if we want to reach across a larger distance of, say, 100 km and to a larger number of people, then we will have to use some other method.

Suppose, we want to send bags of wheat, say from Delhi to Calcutta, which we know is 1500 km away. One of the simpler ways of doing it is, of course, to send them by a truck which can travel long distances speedily. The goods truck is then the 'carrier' of the wheat bags. It is, of course, necessary to make sure that the bags are unloaded at Calcutta. Similarly, it is possible to carry speech or music from one place to another with a 'carrier' known as radio frequency waves which can travel long distances. Their interesting property is that they travel at the speed of light (3,00,000 km/s). Therefore, the speech or music carried by them reaches long distances almost immediately. The instrument that is used for this purpose is called *radio transmitter*. A simple radio transmitter is shown in Fig. 32.4. The radio frequency waves are made to take on sound signals in the part of the transmitter called *modulator* and this process is called *modulation*. This modulated r f energy is amplified and given to the aerial from where it travels out.

Such r.f. transmitters radiating r.f. waves carrying music, etc., are called radio stations. There can be many such stations and it is, therefore, necessary to distinguish one from the other This is done by deciding beforehand the frequency of the r.f. energy which a station is supposed to radiate out. Thus, at any time in a country no two radio stations use the same radio frequency.

32 1—4 Radio receiver

As the radio frequency waves can travel great distances at the speed of light, we chose them to carry the speech or music. These waves are electromagnetic waves and cannot be heard by the human ear Thus, it is necessary to obtain the speech back from the carrier r.f. waves. This is done by radio receivers or radio, as it is commonly known. Fig. 32.5 shows the main parts of a radio. A radio will have to pick up a portion of the energy from the modu-

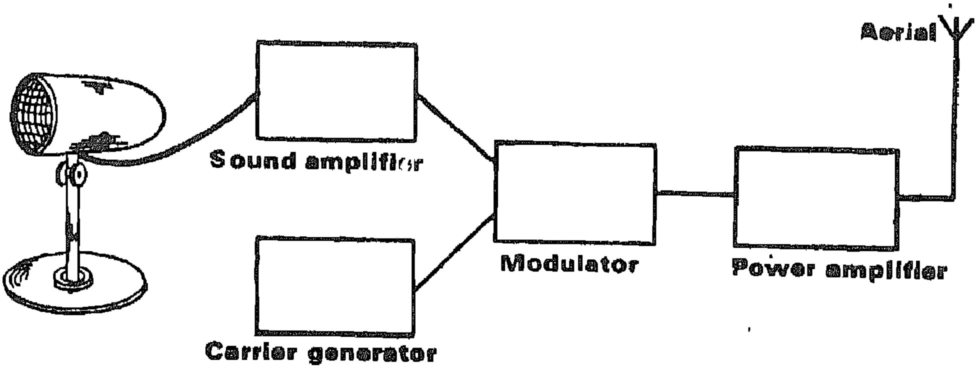


Fig. 32.4 Radio broadcast transmitter block diagram

lated r.f. waves which travel past it. This is done merely by having a proper electrical conductor standing in the path of the r.f. waves. This is called *aerial.* It is seen on the house-tops often as a wire hung between two poles with one end of this wire connected to the radio. In modern portable radios, it is made a part of the radio itself.

The aerial can pick up the radio frequency energy from all directions and, hence, if there are a number of transmitters sending out music programmes, one can easily imagine the jumble that will be created. It is, therefore, necessary to distinguish one radio station from the other. This is easily done if the carrier of one station is kept different from the other, and the radio is provided with a method of selecting stations. Fig. 32.5 shows a station selector connected to the aerial. Selecting a station this way is also called *tuning in the station.* Every radio has an arrangement called *tuning* for this purpose. Having obtained the r.f. energy of the station of our choice, we now have to obtain the speech in which we are really interested and discard the r.f. carrier which helped it to travel long distances. This is achieved with the help of a demodulator shown in the figure Now, we have electrical energy corresponding to the speech message but it is very weak and cannot be used directly to produce sound. It is, therefore, amplified and fed into a loud-speaker in a way similar to the public address amplifier which we discussed earlier.

We have been saying that the r.f. energy can travel long distances in a

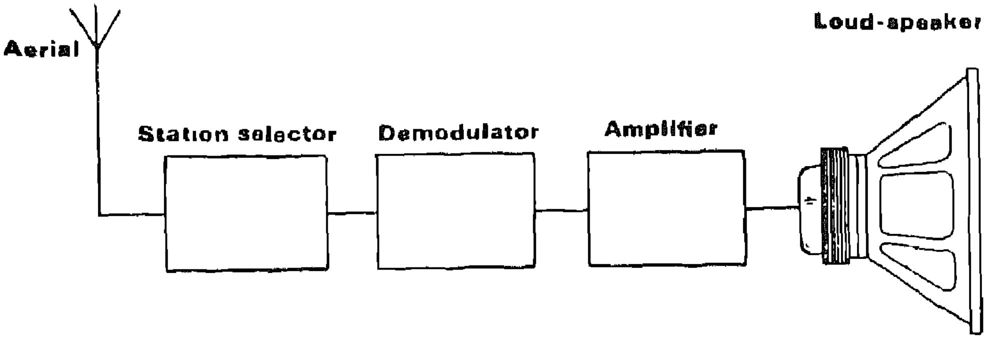


Fig 32 5 Radio receiver block diagram

straight line. However, like our goods truck, it cannot reach long distances on the earth, because the earth's surface as we know is round. If so, we cannot use radio waves for distances more than, say, a few kilometres. However, we know that it is possible to hear a distant station in Sri Lanka at Delhi which is thousands of km away from it.

For waves which travel in a straight line, the curved surface of the earth is no doubt an obstruction Suppose, you are sitting in one room and your friend in the other room separated by a door. The wall is an obstruction and you cannot directly see what he is doing in the room. However, if you properly place a mirror near the door, it is possible to see him from your place. Thus, it is possible to avoid an obstruction by reflecting light waves from a mirror to travel from one place to the other around the obstruction.

The earth's atmosphere becomes rare with height. A large part of the radiation from the sun, consisting of ultraviolet rays, ionise the air molecules of the upper atmosphere. The layer of the atmosphere where it is in the ionized state is called *ionosphere* and it covers the earth like a shell. The ionosphere has a property of reflecting radio waves, particularly of a short wavelength, back to the earth Thus, it acts like a mirror for them and, hence, can be used to overcome the obstruction posed by the earth's curved surface. It is for this reason that we are in a position to hear stations at large distances and send telephone messages to distant countries using short-wave transmission.

The ionosphere, however, is not a good mirror for medium wave and very high frequency radio waves, like the ultra high frequency and microwaves, which travel through it without the change of direction.

32 1—5 Television

Radio is familiar to us; it is seen even in villages. Now-a-days, we see another means of entertainment in which moving pictures can be seen That is *television*. It is is likely that there is one in your neighbourhood. The remarkable difference between radio and television is that one can see and hear events happening at large distances on television, whereas one could only hear speech or music at large distances on radio.

However, there are many similarities between the two. Television receives electrical energy corresponding to the picture and sound through an aerial which is prominently fixed on the roof-top of a house. The basic method of sending speech and picture from the television centre or station is similar to that used for radio transmission. The television centre radiates the r.f. energy as the carrier of sound and picture in all directions.

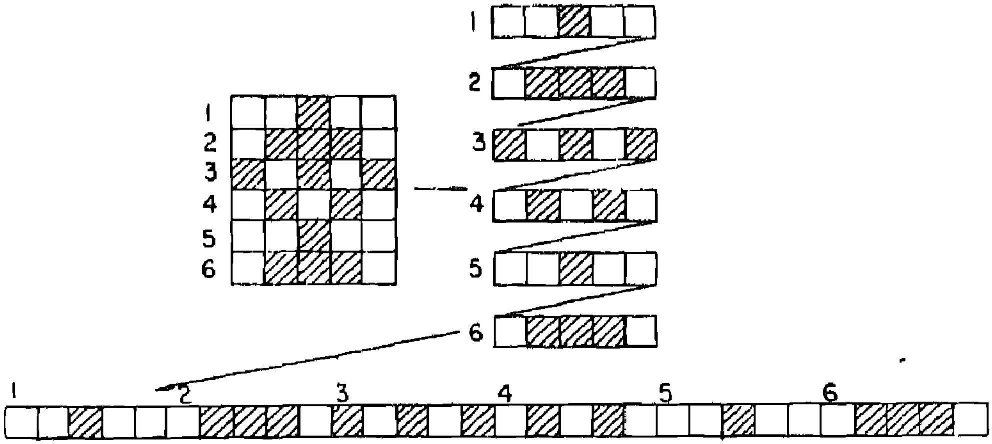


Fig 32,6 Conversion of a picture into a string of radio signals

The most interesting part of television is the method that is used to obtain pictures on the television screen. Take, for example, a simple picture as shown in Fig. 32 6. Suppose, we cut the picture into a number of strips horizontally. We also take care to see that we number them properly from the top to the bottom of the picture. Next, the strips are stuck end to end in such a way that the right end of the first strip is stuck to the left end of the second and the right end of the latter is stuck to the left end of the third, and so on. We now have our original picture converted into a long tape. Imagine a friend of yours who would like to see the picture as it was. What should he do ? Obviously, he should cut the tape at the places where the strips were originally stuck and stack these strips according to the number. It is, of course, necessary that you should tell him beforehand how he should do the reconstruction. Otherwise, he will spoil the tape and hence the picture.

At the television centre, there is a special camera which views the picture and converts it into a stream of electrical voltages in the same way as we made the tape from our picture. This stream of electrical energy is taken on a suitable r.f. carrier and radiated to larger distances At the television receiver in our house, this energy received by the aerial is separated from the carrier in the form of sound and stream of electrical voltages which correspond to the picture. There is an arrangement in the television set to obtain pictures from the stream in the form of strips and to arrange them properly on the television screen in the same way as your friend did with the tape For good reproduction, the strip should be thin and large in number to cover the full frame of the picture Similar to the way you told your friend beforehand where to cut the tape for obtaining the strips, the television receiver also receives instructions from the station to cut the stream of electrical voltages in the receiver and arrange them according to the rule.

The method of obtaining a picture frame can be used for moving the picture in the same way as movies make use of the persistence of human vision. The picture frame, if repeated a number of times, say, 50 times a second, will now appear natural and the actual scenes happening at one place are seen at the far-away places almost instantaneously.

If we are standing on a flat even ground, we can see around us up to a distance of approximately 4.5 km, as the earth is round. If we climb a tree to the height of 10 metre, then we would be able to see up to 12 km on a clear day Similarly, if we want to send television signals to a greater distance, we will have to increase the height of the transmitter antenna. The height of the television antenna tower of Bombay station is 300 metres. Now, suppose, we want to cover whole of India by a single television transmitter, then the antenna height will have to be more than 210 km This we can achieve only if we make use of a statellite as was done recently in the SITE experiment when 2400 villages spread all over India received the television programmes. These programmes were transmitted from the Earth Statellite Communication Centre, Ahmedabad to a satellite which received them and then retransmitted them back to all these villages.

32.1—6 Radar and sonar

The reflection of waves is an interesting phenomenon in many ways For example, when a person shouts in the direction of a small cliff far away, he hears an echo of his shout after a short time. The reflected sound is often muffled and weak We do not hear echoes in our classrooms that easily. It is not because the waves do not reflect from the walls of the room, but the time between the original sound and its reflection is so short that the human ear cannot make out the difference. Thus, to obtain, information about the reflected waves, we need an ability to measure the time duration between the original and the reflected waves. If we can measure the duration accurately, we can also measure the distance between the source of sound and the body that reflected it. This method of measuring distances is called *ranging*.

There is another interesting feature of the echo. Its strength depends upon the nature of the body that reflects the waves. For example, if the area of the wall is small, the reflected wave will be so feeble that the echo may not be heard. Similarly, if we have a heap of cotton instead of the big wall, the echo will again not be heard at all Thus, it carries with it some rough information about the type of the reflector.

Echoes, or the reflection of sound waves is familiar to us. But the reflection of waves is a general property of all waves, whether sound or electromagnetic. Suppose, we use r.f. waves, which are electromagnetic waves and travel at the speed of light, to produce reflections. Since their speed is many times higher than that of sound, the time duration between the original wave and the reflected wave will be very much shorter.

An instrument, which produces r.f. waves and measures such short durations accurately, used for measuring its distance from a reflecting body is called *Radar* (Radio Detection and Ranging) (Fig. 32.7). It is used for locating and ranging of aircraft, obstacles in the path of seafaring ships and also for tracking cyclones and cloud formations. It is an essential instrument for defence against the enemy aircraft.

Let us say it takes 10^{-3} second for these radio waves to travel from the radar to aircraft and back. We know that radio waves travel 3,00,000 km per second. Therefore, the distance travelled by these radio waves is 300 km or we can say the aircraft is 150 km away.

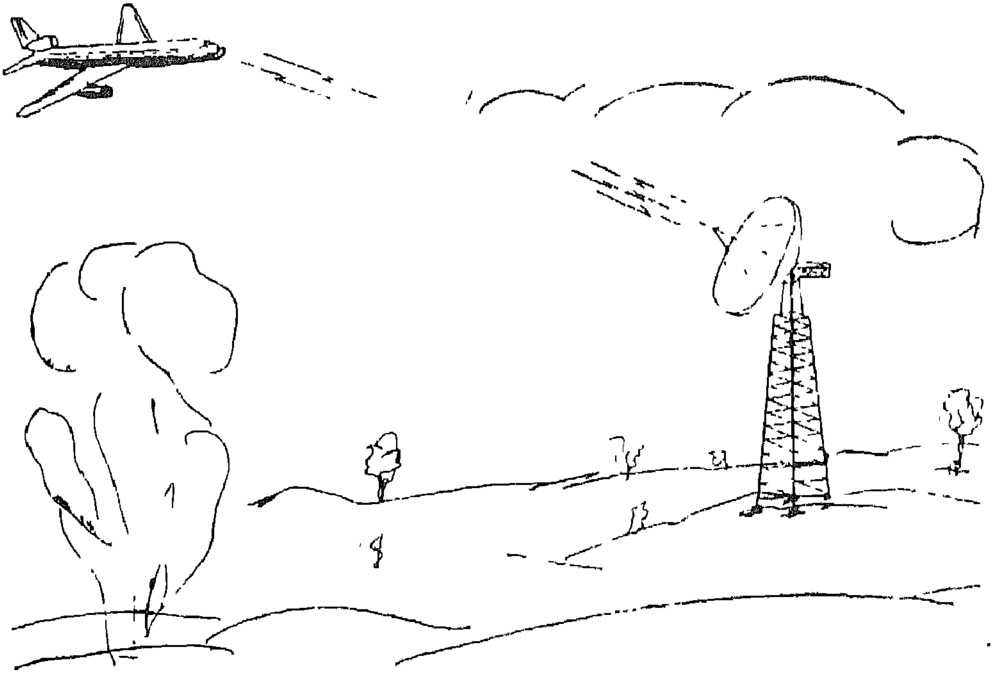


Fig. 32 7 Radar

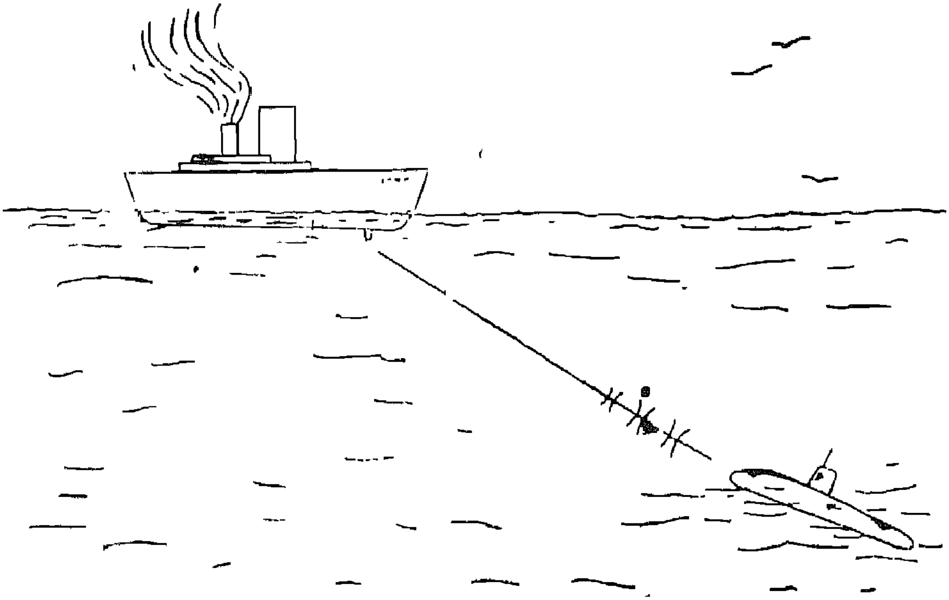


Fig. 32.8 Sonar

Sound waves can also be used in a similar way. An instrument which produces sound waves and measures short-time durations of the reflected sound waves is called *Sonar* and is used by ships for measuring the water depth, and for ranging shoals of fishes. Our Navy uses it to locate submarines and enemy torpedoes which are weapons used to destroy ships (Fig 32.8).

32 2 Chemistry in industry

32.2—1 Portland cement

We see around us tall and huge buildings, bridges, tunnels, etc which are constructed with bricks, sand, lime, iron, Portland cement and some other materials. In the absence of cement, it would be difficult to conceive of such gigantic structures Most of us have seen cement. Let us try to know about such a useful building material, *cement.*

What is Portland cement ?

One of the most important building materials presently in use is Portland cement. It is essentially a finely ground mixture of aluminates and silicates of calcium with varying compositions. In the nineteenth century, it was found that on mixing with water, the above stated mixture set to a hardened mass resembling the famous Portland rock of England Since then this mixture has been called Portland cement. It forms the basis for a number of cement products.

What are the raw materials required for the manufacture of Portland cement ?

The basic raw materials required for preparing Portland cement are limestone or chalk ($CaCO_3$), clay or shale (aluminium silicate) and a small amount of gypsum ($CaSO_4 . 2H_2O$) However, the choice of raw materials depends largely on the location of the manufacturing plant.

How is Portland cement manufactured ?

Limestone and clay are first ground together without or with water to a fine powder. The dry powder (or wet slurry) is then fed into a rotary kiln, where length may be as short as 50 metres if a dry powder is used. The diameter of the rotary kiln varies from 2—6 metres (Fig 32.9). The kiln is kept in a slightly tilted position and is made to rotate slowly. Hot gas produced by some burning fuel, e g., powdered coal, oil or gas, is allowed to move upward through the kiln. The temperature at the hottest part in the kiln is about 1500—1600°C. It takes about two hours for the feed mixture to travel through the entire length of the kiln. Chemical reaction takes place between the limestone and clay inside the kiln. A mixture of the aluminates and the silicates of calcium is thus formed in the form of *clinker* (3-10 mm size). The clinker is cooled in a rotary cooler and a small amount of gypsum is added to it. This mixture is ground to a very fine powder which is called *Portland cement* and put in bags or drums, or stored in big tankers. The addition of gypsum delays the initial setting time of cement

The average composition of cement in terms of CaO, SiO_2 and Al_2O_3 is

CaO	—62%
SiO_2	—22%
Al_2O_3	— 7%
Other oxides	— 9%

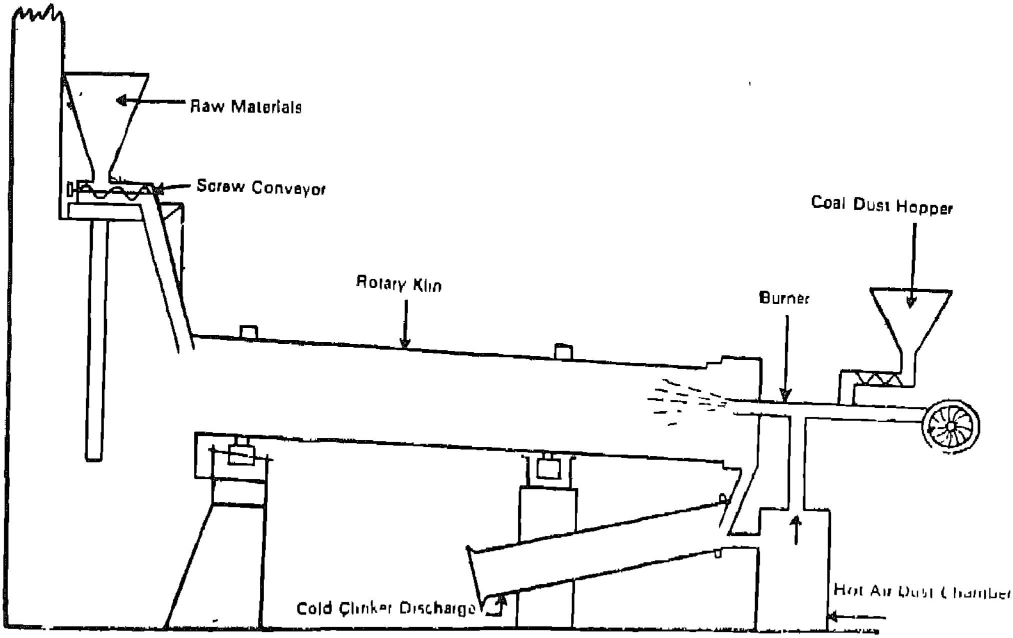


Fig. 32.9 Manufacture of cement

How do we use Portland cement ?

A mixture of Portland cement, sand, gravel (coarse and fine) and water, when allowed to stand, sets to a hardened mass called *concrete*, a very important building material. The coefficient of expansion of concrete is almost equal to the coefficient of expansion of iron. Therefore, concrete is reinforced by placing an iron frame-work inside it.

Cement, when mixed with sand and water, forms *mortar*. In mortar, cement and sand are usually mixed in a ratio of 1:3

Cement is used for the construction of buildings, dams and highways mostly as concrete or reinforced concrete Some other uses of cement are as plasters and mortar used for binding bricks and stones.

The Cement industry in India has taken very rapid strides to achieve self-sufficiency. Most of the machines and their spare parts, which are required for this industry, are now manufactured in our country. The plants manufacturing cement are located at places which have nearby deposits of limestone and coal and transportation for the product is readily available. Some of the leading cement manufacturing plants in India are located at Azamabad (Andhra Pradesh), Vadodara (Gujarat), Mundwa (Maharashtra), Ambattur and Madukarai (Tamil Nadu), Bokajan (Assam), Churk, Dalla and Dehradun (Uttar Pradesh), Sindri (Bihar), Katni (Madhya Pradesh), Urkunta (Mysore), Paonta (Himachal Pradesh) and Lakheri and Chittorgarh (Rajasthan).

32.2—2 Glass

The importance of glass in the development of modern civilization is unquestionable. Astronomy would not have developed without a telescope. Control of several diseases caused by bacteria and viruses would not have been possible in the absence of a microscope. In both, telescope and microscope, optical components made out of glass are used. The original discoverer of glass is not known exactly. However, the glass or a glass-like material was known to Egyptians by 3800 B.C. The art of making glass did not improve much during 3800 BC to 1900 AD. In modern times, glass has undergone a remarkable evolution through the efforts of chemists. We are already aware of the glassware used now-a-days in our day-to-day life.

What is the chemical nature of glass ?

Before understanding the chemical nature of glass, let us try to focus our attention on one or two points which have a direct bearing on the nature of glass. We already know that a crystalline solid, when heated, invariably passes to a liquid state at a fixed temperature. There are some solids, however, which lose their rigidity gradually and therefore do not have any fixed melting points. It is, however, possible to cool a liquid below its normal freezing point, without any solid being formed. The liquids which can be cooled to a temperature below their normal freezing point are said to be *supercooled.* Such supercooled liquids may be quite stable provided all traces of the solid form are excluded.

Glass is just such a supercooled liquid which has been cooled so far below its melting point that the rate of crystallization is infinitely slow. Ordinary glass is a homogeneous mixture of silica and the silicates of sodium and calcium.

Glass has no definite composition or melting point. B various constituents but also their relative quantities, possessing different properties can be prepared. The qu glass depend on the purity of the materials used for prod

How is ordinary glass manufactured ?

Glass is mostly produced by using the same basic from sand), soda ash (Na_2CO_3) and limestone (CaCO heated together in a furnace (made out of fire-clay) electric current to a temperature of about 1400°C Tł take place:

$$Na_2CO_3 + SiO_2 \longrightarrow Na_2SiO_3 + CO_2$$
(Sodium silicate)

$$CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2$$
(Calcium silicate)

At 1400°C, silica dissolves in the molten mass of silicates. On rapid cooling, this molten liquid mass form mate composition is $Na_2SiO_3 . CaSiO_3 . 4SiO_2$. This gla bottles, light bulbs and sheet glass for glazing, etc. This g soft glass because it softens easily on heating. If small and alumina are added to this glass during its productio glass is obtained which can be worked in a machine.

Objects made out of ordinary glass are slowly coole ovens. This process is called *annealing of glass*. Objects allowed to cool rapidly, are very brittle.

Are there any other types of glass ?

There are different types of glass prepared by varying their amounts.

(a) ***Hard glass:*** It is prepared by using potassium ca sodium carbonate, its softening temperature is higher tl Therefore, it is called hard glass. It is used for making holl shapes, especially for laboratory use.

(b) ***Flint glass:*** It is made by using sodium carbo bonate, lead carbonate, boric oxide and silica. This typ making lenses and prisms for optical instruments.

(c) *Pyrex glass:* Pyrex glass is made by using a mixture of about 80% of silica, 12% of boric oxide and 3-4% of sodium corbonate and aluminium oxide each This glass is heat-resisting and therefore it is used for making laboratory apparatus and cooking utensils.

(d) *Fibre glass:* It is produced by drawing molten glass through fine nozzles into filaments. It is used as a very effective insulating material for electricity, sound and heat. Plastics is reinforced by using fibre glass. It is also used for making heat-resistant fabrics.

How is coloured glass produced ?

Beautiful objects made out of glass bearing different colours are a common sight. The production of coloured glass is effected by adding small quantities of suitable metals or metal salts to the molten mixture of silicates. The choice of the salt depends on the colour to be imparted. The green and red glasses used for traffic signalling are prepared by adding sodium chromate and selenium oxide, respectively Addition of cobalt oxide imparts a deep blue colour whereas cadmium sulphide imparts bright yellow colour. For making glass for goggles, which protect the eye from harmful rays from the sun, iron (II) oxide is used.

32.2—3 Plastics and fibres

Plastics and fibres are among the most important synthetic materials which are presently used in daily life. The pen we write with, the tooth brush, the comb, soap boxes, radio cabinets, switches and films, etc., are all made out of plastics. Similarly, textiles made out of nylon, dacron and orlon, etc., which are synthetic fibres, are very commonly used now-a-days.

What is a plastic ?

Plastics are compounds having large molecules, or compounds of high molecular weight from 10^3—10^7. Cellulose is a naturally occuring large molecule and is used in the manufacture of the plastic. For making the articles of daily use, however, the large molecules are manufactured either by the combining together of a large number of small molecules, or by a chemical reaction in which a molecule of water is eliminated between each pair of simple molecules.

Some commonly used plastics are polyethylene, bakelite, teflon, nylon. terylene, polyvinyl chloride (PVC) and orlon

What are natural and synthetic rubbers?

The use of rubber for making articles of several kinds is well known. Rubber is obtained from the latex of certain species of trees. Most of it is now derived from the plantations of cultivated trees in Malaya, Sri Lanka and Indonesia. Natural rubber is produced in a small quantity in India also. The quality of natural rubber, obtained from the latex of certain species of trees, is greatly improved upon by some chemical treatments The supply of natural rubber is not adequate to meet its growing demand in industry. To meet this demand, therefore, chemists occupied themselves with the task of producing *synthetic rubber* or rubber-like material. There are several synthetic rubbers, e.g , Buna N, Buna S, neoprene (or duprene), alloprene, etc , used for making protective paints resistant to acids and alkalies, heat and sound insulators, tubes and tyres, etc.

32.2—4 Soaps and synthetic detergents

Soap-making is a large industry in our country. Apart from cleaning our bodies, soaps and detergents are required for laundry, textile manufacture, sanitation, food processing, shaving soaps, shampoos, synthetic rubber, paints and paper industries, drilling fluid, sprays for agricultural use, glass cleaners, waterproofing cement, scouring powders (used for cleaning utensils , etc. Let us study about the chemical nature of soaps and synthetic detergents.

What is soap?

Commonly used soap is a sodium salt of a fatty acid (e g., oleic, stearic, palmitic) obtained either from plants or animals. The quality of soaps largely depends on the raw materials used or the process used in manufacturing them The soaps obtained from above acids are known as sodium oleate, sodium stearate and sodium palmitate, respectively.

How is soap prepared?

It is easy to prepare soap at home or in laboratory.

In a beaker 10 ml of cotton seed (Binaula/linseed/soyabeen/olive) oil is taken and 10 ml of a 40% sodium hydroxide solution is added to it. On boiling this mixture, which is continuously stirred, a thick paste is obtained. During preparation of soap, some hardening agents, e.g. water-glass or sodium carbonate, are also added to the paste to harden the soap. This reaction between the oil and the alkali can be simply represented as :

$$\text{Oil (fat)} + \text{base} \rightarrow \text{soap} + \text{glycerol}$$

When the reaction is complete, both the products, i e. soap and glycerol (commonly known as *glycerine*), are in the form of solution in water. Some sodium chloride is added to this solution as a result of which the soap is precipitated out. The soap so obtained is then dried and cut into bars and cakes.

For making good quality soaps, hydrogenated oils are used because they contain a large proportion of fatty acids.

Modern commercial soaps, apart from containing the genuine soap, also contain disinfectants, medicaments of various kinds and bleaching materials also These materials are incorporated keeping in view the special purpose for which the soap is required

How does soap behave with hard water ?

We already know that the presence of soluble salts of calcium and magnesium makes the water hard Therefore, when soap is brought in contact with water containing the ions of calcium and magnesium, the soap is decomposed forming insoluble calcium or magnesium salt of the fatty acid which is separated out as a scum. This reaction can be simply represented as follows :

$$\left.\begin{array}{c}\text{Soluble soap (sodium stearate, etc)}\\ + \\ \text{Calcium bicarbonate (sulphate, etc.)}\end{array}\right\} \rightarrow \left\{\begin{array}{c}\text{Sodium bicarbonate (sulphate, etc.)}\\ + \\ \text{Insoluble soap (calcium stearate, etc.)}\end{array}\right.$$

The insoluble soap sticks to the pores of the cloth making it difficult to clean. To get rid of this difficulty, chemists started looking for some other cleansing agents. Such cleansing agents, known as soapless soaps or *detergents*, were first synthesized in Germany during the First World War.

What is a detergent ?

Detergents are very much different in chemical nature from an ordinary soap or the salt of a fatty acid. They are synthetic organic chemicals and have better wetting properties than soaps. If unsaturated hydrocarbons of the ethylene type, containing between ten and eighteen carbon atoms, are allowed to react with sulphuric acid, some organic acids are formed. The sodium salts of these acids exhibit a remarkable wetting and consequently cleansing properties. Such compounds are known as synthetic detergents. The detergents do not form any insoluble compounds with calcium or magnesium ions and are therefore advantageously used even with hard water.

Several synthetic detergents under different trade names are now-a-days sold in the market.

32.3 Agricultural practices and animal husbandry

32.3—1 Crops and factors influencing crop production

Agriculture in the wider sense is the study of the science and art of production of plants and animals useful to man Agriculture includes the cultivation of land, and breeding and management of crops and animals. It is derived from the Latin words *Ager* which means field and *Cultura* which means cultivation. Wherever we live, we are dependent on agriculture for our food, clothing and shelter, and for many other things we use in our daily life.

Horticulture, (*Hortus*—Garden, *Cultura*—Cultivation) a branch of agriculture, is the science and art of growing vegetables, fruits and ornamental plants.

Agriculture is still the largest enterprise in our country and nearly 70 per cent of the population is employed in this sector. Agricultural production has to be maximised to meet the requirements of increasing population in our country A new strategy of intensive agricultural production based on the application of science has been adopted to make the country self-sufficient in its food requirements. Speedy improvement of agriculture is vital to the progress of our country. The new strategy depends upon making the best use of the soil, water, climatic factors, available resources and on adopting improved agricultural practices. India has achieved significant increases in yields of crop plants. To some extent, increase in crop production has been achieved by bringing more land into cultivation There is a limit to increase in area as the forest lands and pastures should not be brought into cultivation. Therefore, the production from the cultivated lands is being continuously increased by following improved agricultural techniques.

FACTORS CONTROLLING CROP PRODUCTION

The four most important requisites of successful agriculture are : soil, water, air and sunlight.

Climate is the sum total of all environmental factors affecting organisms. Variations in the availability of water, sunlight and temperature mainly constitute the climate of a region. Our soil and climates show distinct regional patterns. Favourable climatic conditions are essential for obtaining good crop yields. Prevailing local weather conditions also influence crop production. India is a vast country. There are wide variations in the climate along the length and breadth of our country. The climate ranges from tropical to subtropical to temperate conditions. Excessive rainfall, droughts and floods are a recurring feature and they cause serious losses in foodgrain production in our country

SOIL

The soil consists of the outer thin layer of the earth's crust The soil is called the 'Mother Earth'. The constituents of the soil are water; air; organic matter (decaying plant and animal material is known as humus); inorganic matter (mineral matter); living organisms: (a) Micro-flora: Bacteria, Actinomycetes, Algae and Fungi (b) Micro-fauna: Protozoa, Nematodes; besides worms, insects of different sizes and kinds.

The texture of the soil may be coarse (sandy), medium (loamy) or fine (clayey). The primary particles of sand silt and clay determine the soil texture. The different proportions of these particles constitute different soil textures.

Soil is the natural medium which supports the growth of plants on the earth's surface. Plants are anchored to the soil. Soil serves as the reservoir of nutrients and water for plants. Plants are also being cultivated now in solutions containing the required mineral nutrients.

The soil texture and the content of organic matter, water and minerals control the physical and chemical properties of soil. With the help of your teacher you may analyse the soil by simple methods to study its physical and chemical properties.

WATER

Plant needs water during its various stages of growth and development Water requirements of different crops and of the same crop at various develop mental stages vary. Lack of sufficient water at germination, tillering, flowering and grain filling stages lead to reduction in the yield or crop failure. Crops have to be adequately irrigated, taking into consideration their water requirements.

Out of about 164 million hectares (1973-74) of land under cultivation in our country, only about one-fourth of the area is under irrigation. The cultivation in the remaining three-fourths area still depends on rainfall which is largely uncertain.

SUNLIGHT

One of the favourable features of Indian agriculture is the availability of abundant sunlight and favourable temperature throughout the year. This ensures proper growth of the crop throughout the year in several areas, if other facilities are made available Double or multiple crops can be raised in these regions by cultivating early maturing varieties. The following inputs are the most important for agricultural practices and require greater attention.

1. Use of the improved varieties of crop plants and improved cultivation practices.
2. Application of proper manures and fertilisers.
3. Adequate and timely plant protection measures.
4. Adequate and timely supply of water for irrigation

You will learn about these practices in some detail in the following pages.

The climate in our country is variable throughout the length and breadth of the country. Taking advantage of the climatic variations, a large number of crops are cultivated in our country.

CROP PLANTS

Crop plants can be classified in several ways. One of these would be by taking into consideration the products obtained from them as shown below:

Cereal or grain crops: Rice (Fig. 32.10), Wheat, Barley, Oats and Maize.

Millets: *Sorghum* (Jowar or great millet), *Ragi* (finger millet) and *Bajra* (pearl millet).

Fiber crops: Cotton and jute.

Pulses (Legumes): Red gram (pigeon pea, *Arhar*, *Tur*), Black gram (*Urad*), Green gram (*Moong*) and Bengal gram (*Chana*).

Beans: Peas, Soyabean, Cowpea, Lentil grain and Groundnut.

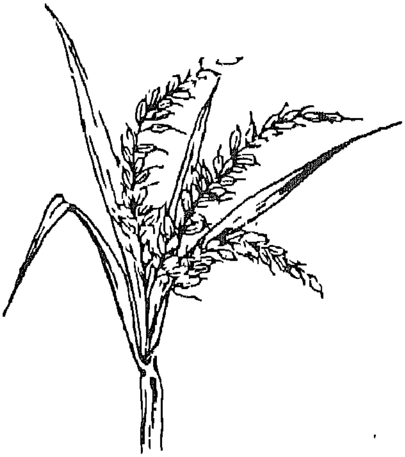


Fig. 32 10 Grain crop · Rice

Oilseeds: Linseed, Mustard, Groundnut, Soyabean, Sunflower, Safflower, Castor and Cotton seed.

Root Crops: Carrot, Turnip and Sweet Potato.

Tuber Crops: Potato, Tapioca, Ginger and Turmeric.

Sugar crops: Sugarcane and Beet root.

Plantation crops· Coffee, Tea, Rubber and Coconut.

You may collect some of the different plants growing in your neighbourhood. Examine their external characters and differences.

HORTICULTURAL CROPS

You know what horticulture means. Horticulture deals with the growing and production of vegetables and fruits and the management of orchards and parks. The cereal content of the Indian diet is unusually large. The increasing population requires increase in the production of cereals. This has its own limitations. It is very essential to take to supplementary and substitute forms of nutrition such as vegetables, fruits, milk, milk-products, egg, poultry, animal fats and proteins in human diet.

At present the diet of an average Indian contains 30 gm and 80 gm of vegetables and fruits respectively. His counterpart in the advanced countries consume 316 gm and 362 gm of vegetables and fruits respectively. Thus, there is a greater need for increasing the production of horticultural crops. Moreover, vegetables provide proteins, carbohydrates, mineral salts and vitamins.

The following are some examples of the vegetables and fruits of our country :

Vegetables: Potato, Tomato, Brinjal, Cabbage, Onion, Lady's finger, Garden pea, Radish, Beet root, Turnip, Carrot, Beans and Leafy vegetables.

Fruits: Apple, Plantain, Orange, Guava, Grape, Mango, Papaya and Pineapple.

32.3—2 Various agricultural practices

The yield of a crop can be increased by following a number of improved practices from sowing to harvesting. Proper attention has to be paid to all the practices. Neglect of one or more of these practices leads to reduction in the yield. Implements required for use at the various stages of crop production should be good and effective. The use of tractors and allied machinery, which has been contributing significantly to the improved agricultural practices is broadly the same in different parts of the country but varies in detail from crop to crop. Various practices for increasing crop yields are continually being improved by agricultural scientists throughout the world. You will learn about the various agricultural practices one by one in the following pages.

ROTATION OF CROPS

If only one type of crop is grown in succession on the same field, the yield may decline and the crop may be more prone to diseases and pests. In order to avoid this, different types of crops are grown in succession in a field. A pulse crop is generally grown between two cereal crops to restore the fertility of the field.

VARIETAL IMPROVEMENT

The improvement of crop varieties is an ever continuing process in modern agriculture. Do you know that a number of wheat and sugarcane varieties of earlier years have gone out of cultivation and are replaced by better types ? The varietal improvement is the work of the plant breeders. The

Fig 32 11 An improved variety of wheat
(***Courtesy*** · Directorate of Extension, Deptt. of Agriculture, Govt. of India)

following are some improved high-yielding varieties of certain crops:

Rice	IR-8, Jaya, Padma, Bala, Jagannath, IET-1039, T-141 and Cauvery.
Wheat	Sarbati Sonora, Sonalika, Kalyansona, Hira Moti, RR-21 and UP-301 (Fig. 32.11).
Maize	Ganga-101, Ranjit and Deccan Hybrid.
Lady's Finger	Pusa Savani
Brinjal	Pusa Purple, Long, Pusa Kranti and Muktakeshi.

SEED TREATMENT

Treatment of seeds with fungicides is essential to check the spread of seed-born diseases. The seeds are treated with chemicals like Agrosan or Ceresan. This treatment also protects the seedlings from the attack of many diseases.

SEED BED PREPARATION AND CARE OF SEEDLINGS

In the case of paddy and many vegetables, the seeds are first sown in a nursery bed and only after they attain certain age they are transplanted to the main field. The seed bed is properly ploughed and prepared so that it should be soft and loose enough to permit the growth of the tender roots. The level of the seed bed is kept uniform in order to ensure uniform distribution of irrigation water. Frequent and adequate irrigation in nursery is very essential as the plants at this stage are more likely to dry up than the adult plants. It is neces sary to remove the weeds as they compete with the crop plants for water, nutrients and sunlight. Seedling must also be protected from the attack of diseases and pests by spraying chemicals like Parathion, Sevin, Dimecron and Rogor.

TRANSPLANTING

The practice of planting the seedlings from the nursery to the main field is known as transplanting. Transplanting allows for selection of seedlings, better penetration of roots in the soil and better shoot development. Transplanting is a common practice in the cultivation of rice and many vegetables. This is practiced sometimes in wheat cultivation also. The main field is appropriately ploughed and manured. When the seedlings are 4 or 5 leaved, transplanting is done. During transplanting, proper distance is kept between plants and rows to enable the plants to receive sufficient sunlight and water, and for easy interculture.

FERTILISER APPLICATION

To obtain better yields it is necessary to apply fertilisers. Fertilisers are applied keeping in mind the natural soil fertility and crop requirements. The total amount in case of nitrogenous fertilisers is applied in split doses, two or three times, while others are added basally at the time of transplanting. You will learn more about the fertilisers in the following lesson.

IRRIGATION

For the survival and proper development of plants, irrigation is necessary. Roots fail to develop and elongate in a dry soil. The number of tillers (aerial branches in cereals) also get reduced in a dry soil. The crop is irrigated according to its water requirement and soil characteristics. Irrigation practices, in cereals thus vary for different types of crops and soils. Irrigation is essential during the seeding, tillering, flowering and grain filling stages of the crop. There should be provision for draining the excess water. The rice plant tolerates standing water (water logging) in the field, while in the case of other crops like maize and vegetables the excess water must be drained out. Heavy rains during the harvest season of cereals cause crop losses.

WEED CONTROL

Weeds are undesirable plants in crop fields. The weeds are classified as graminaceous (*Monocotyledonous*) and non-graminaceous (*Dicotyledonous*) weeds. ***Hariali*** or Doob grass (*Cynodon dactylon*) is a graminaceous weed. *Choulai* (*Amaranthus* sp.), growing in a field of tomatoes, is a dicotyledonous weed. Weeds compete with the crop plants for water, nutrients and sunlight and thus grow at the expense of crop plants. The weeds are first removed before sowing or transplanting by handweeding or using a plough or a harrow. Weeds reappear during crop growth and are removed either by hand-weeding or by spraying weedicides (weed killing chemicals) like 2, 4-D (2, 4 Dichlorophenoxy acetic acid), MCPA (4-Chloro-2-methyl 1-phenoxy acetic acid) and Simazine. Several spraying appliances are in use today to apply these chemicals.

CONTROL OF PLANT DISEASES AND PESTS

Crop plants are attacked by a number of diseases, which lead to considerable crop losses. These diseases are caused by fungi, bacteria and viruses. Some diseases are transmitted through the seed and are called the seed-borne diseases. Others are soil-borne or air-borne. Various fungicides are available to control the diseases Some of the high yielding varieties of crop plants are susceptible to several pests which are generally of the insect group. By spraying pesticides (Fig. 32.12) or following other control measures, the pests can be controlled.

Fig. 32.12 Spraying of pesticides on wheat plants.
This prevents several diseases of crop.
(*Courtesy :* Directorate of Extension, Deptt. of Agriculture, Govt. of India)

USE OF PLANT GROWTH REGULATORS

The researches in plant physiology have resulted in the development of a number of chemical substances which influence the growth and development of plants. There are many types of these chemicals which have specific action on plants; they are auxins, gibberellins, cytokinins, abscisin and growth inhibitors. These growth regulators have found a place in modern farming techniques, particularly in the case of horticultural crops for growing better quality produce.

MULTIPLE CROPPING

One of the contributing factors to the increase in food production in India is the multiple cropping. This involves raising two to four crops in succession in a year from the same field. This becomes possible by proper management and by the use of short duration varieties of crops Proper irrigation facilities are essential for multiple cropping. Through this technique we can now harvest upto four crops whereas it was not possible to harvest more than one or two in the past. Multiple cropping has not been adopted in all regions of our country. Its extension holds the key to the food problem of India.

In order to learn the different agricultural practices, you must visit the nearby agricultural farms or vegetable gardens. You should try to grow a kitchen garden either in your home, or in school, or in both the places. By this experience you will learn much. Moreover, whatever little you will produce, will increase our country's food production.

32.3—3 Improvement of crops

Since the beginning of this century, with the emergence of genetics, the crop improvement programme has been brought to scientific level. Crop improvement through breeding now forms the backbone of modern agriculture.

The improvement in crop plants is necessary for increasing the yield and improving the quality of crop. Such improvement is achieved not through breeding alone. For a long time, man has been using various methods for improving the crops. These methods are ploughing the land, irrigation and protecting the crop from diseases. With the development of scientific knowledge and the demand for more food, various new methods for crop improvement are continuously adopted. These practices as you have already learnt are in the form of providing better manures and fertilisers, protecting crops from various diseases and giving proper irrigation facilities Breeding for better seeds, introducing and selecting plants from different localities and acclimatising them and inducing mutations are some of the permanent measures for crop improvement. In this chapter you will study various topics in relation to these aspects.

BREEDING

The main aim of plant breeding is to produce new crops superior to their existing counterparts. By plant breeding method, new varieties resistant to pests and diseases for higher yield and short duration are being evolved. The plant breeder achieves this by artificial crossing or hybridization. Hybridization increases genetic variability. Desirable characters from two or more varieties of plants can be combined by hybridization. Hybridization may be effected between different varieties of the same or different species.

A systematic process is followed to get a better quality of breed. First of all the parents with the desired characters are selected. In the nearly mature bisexual flowers, the anthers are removed with the help of fine forceps. It is done to avoid the chances of self-pollination. Then the emasculated flower is covered with a paper bag, and tagged properly. The tag contains the name of the parent plant, time and date of emasculation and other details After some hours or days, depending upon the crop, the viable pollen grains from the other selected variety are applied on the mature receptive stigma of the emasculated flower.

The fertilisation takes place and all the seeds are collected upon maturity. They are sown and only the plants with desired characters are selected. The seeds of these plants are resown. The cycle of crop raising and selection continues for several generations. Thus, plants with constant characters are finally obtained, which are released to the farmers in different parts of the country.

The NP-52 variety of wheat is a result of a cross between the NP-6 and Pb-9 varieties. It is a high yielding variety with good quality of grain.

The Sone 227, Kalyan 227, Kalyan 567, Pb-18, Sonalika 308, Sarbati Sonora, S-331, UP-301, RR-21, are some of the varieties of wheat developed in India. The IR-8, R-20, Padma, Jaya, Sabarmati and Cauvery are some of the improved varieties of paddy. Besides, there are various improved varieties of bajra, jowar, pulses, maize, sugarcane, jute, tobacco and vegetables which are cultivated throughout the country.

MUTATION

From your earlier study you can understand the role of mutation in the organic evolution. De Vries defined mutation as the process of sudden, discrete and discontinuous changes found at chromosomal level. It is a sudden heritable change in an organism. The mutation can be induced artificially by atomic radiation and different chemical substances.

Mutations help in raising a new variety of crop plant much faster than any other method. However, the use of mutation in crop plants is limited and needs more exploration A variety of wheat, resistant to black and brown rust disease was developed by mutation. The rice with fine grain and tomatoes with more redness were developed with the help of mutation. In India various improved varieties of wheat were produced with the help of mutation. An example is NP 30 with more tillering capacity, dwarf size, and better grain quality.

INTRODUCTION AND ACCLIMATISATION

It is one of the easiest and most rapid methods of crop improvement. The process of introducing new plants from their old locality to a new locality with different environment is called introduction. And their adjustment under this changed environment of the new locality is called acclimatisation.

The introduction of plant may be from one continent to another, as the 'Ridley' variety of wheat introduced in India from Australia. The litchi and loquat were introduced into India from China. There are also inter-state introduction of plants. The NP wheat varieties were introduced to other states from Delhi.

For thousands of years travellers, pilgrims, invaders, explorers or naturalists have been responsible for the introduction of plants from one area to another. In India, the invaders brought cherries and grapes from Afghanistan and Iraq by A.D. 1300. In 1510, people from Portugal introduced maize, groundnut, chilli, potato, papaya and tobacco into India The East India Company introduced tea, litchi and loquat from China and cabbage and cauliflower from the mediterranean region. The botanical gardens also helped in introducing new plants in different regions. For example, the quinine and rubber plants were introduced in India from the New World by the Kew Botanical Gardens, London.

PROCEDURE OF INTRODUCTION

In the past, the process of introduction was very simple and required only a transporting agency. But due to the development of scientific knowledge, the various steps of the process are analysed scientifically and systematic attempts at introduction were made. The process includes the study of the utility of a plant, its type, place of growing and place of introduction, checking, packing and transport of the material.

SELECTION

Selection is one of the oldest procedures of crop improvements. The selection of better quality of crops for further cultivation is also utilised for improving the crop production. In nature, the best adaptive variety of a crop survives while the rest are wiped out in course of time. This is the phenomenon of natural selection and forms a link in organic evolution.

The selection of better varieties of crop can be made artificially from a mixed population. Sometimes the progeny of a single plant with better yield are selected for further cultivation. In case of vegetatively propagated crops such as sugarcane, banana, potato, onion, citrus, etc., a crop is obtained from the single better yielding plant.

In other cases, the bud is selected for further cultivation. Kalyan Sona 227 variety of wheat, resistant to brown rust disease, is selected from the population of the S-227 variety. Ganga and Vijaya, two important selections of wheat, are resistant to black rust disease.

32.3—4 Elements of animal husbandry

Since the dawn of history, man has been domesticating animals in order to use them for work and for food. In the process of domestication, he developed methods for their care, for their feeding and for getting better breeds of animal. For a long time man has been raising the kinds of animals he wanted. For example, dog has been a companion of man for a long time. The animals he raised were livestock like cattle, sheep, pigs and poultry. This knowledge, in course of time, has developed into the science of animal husbandry.

IMPORTANCE OF DOMESTICATED ANIMALS

India is a predominantly agricultural country. Livestock, such as cattle, sheep, goat, camel, horse, mule, yak, pig and fowl play an important role in the rural economy of India. On the basis of utility the livestock can be categorised into three main heads.

MILK GIVING ANIMALS

Cows, buffaloes and goats provide us with milk. Milk is a perfect natural diet. Milk and its products like curd, cheese, ghee are nutritious food

MEAT ANO EGG GIVING ANIMALS

Ducks, fowls, pigs, sheep and goat are the main sources of meat. The poultry also provides us with eggs.

DRAUGHT OR WORKING ANIMALS

Bullocks, buffaloes, camels and horses are used for doing work in the fields. They are also used in transporting essential commodities. Mules are very useful in military operations in mountainous terrain.

Besides the above functions, the livestock provide us with horns, feather, skin and leather. Their droppings and urine are used as manure to enrich the soil fertility.

NEED OF ANIMAL HUSBANDRY

According to the 1961 census, India has a large livestock population of 336.4 million. Inspite of having a large number of milch animals, milk production in India is meagre. The average annual yield of milk per cow is very low and there is wide scope for augmenting the yield.

Table 32.1 indicates the average per capita milk consumption per day in India and some other countries.

We have in our country 80.4 million working cattle. This works out to a pair of working cattle for every 3.8 hectares of cropped area. The cow dung and urine are the common natural manures. In India about half of the total cow dung is utilised as fuel. Urine also is usually wasted. Cow dung is being increasingly utilised recently as a fuel in gobar gas plants It can be used this way both for fuel and later as manure.

TABLE 32.1

India	130 g
U S A.	623 g
New Zealand	637 g
Switzerland	741 g

There is wide scope for increasing the production of meat and eggs in our country. To meet the needs of the population, the production of these is to be increased by about 20 times.

Table 32 2 indicates the annual per capita poultry meat consumption in India and other countries.

TABLE 32.2

India	0.13 kg
U.S.A.	13.18 kg
European countries	2 47—5 95 kg

MANAGEMENT OF LIVESTOCK

The main handicap in the promotion and growth of livestock industry in India are :

1. Adverse climate and environmental factors.
2. Poor genetic potential of the majority of the livestock.
3. The shortage of feeds and fodders.

The problem can be tackled to some extent by adopting improved methods of managements and breeding.

MANAGEMENT

Here the word management is used in a very wide sense and includes feeding, mating, providing drinking water and treating the sick and diseased animals.

FEEDING

Proper feeding is very important to make the inherited qualities of the livestock effective. The cattle feed must be rich in nutrients. It should comprise of carbohydrates, fats, proteins, minerals and vitamins. The cattle feed can be divided into (1) roughages, and (2) concentrates.

Roughages They include the straws of cereals. They are fibrous, coarse and of low nutrient content in general.

Concentrates: They include cotton seed, oilcakes, cereal grains, bran, etc. They are rich in one or more of the nutrients.

An average cow needs a daily ration of 15 to 20 kg green fodder; 4 to 5 kg of dry grass, a good amount of grain mixture and 32 litres of water.

Feeds given to the poultry chiefly consist of cereals, or their by-products. The modern feed for the poultry is the all-mash diet. It is a mixture feed.

Sheep thrive on natural grasses, herbs and farm wastes. They are generally not given any grain except when they are to be fattened for meat Pigs should be given feed of comparatively low fibre content such as cereal grains and their by-products

WATER AND WATER SUPPLY

Pure water in sufficient quantity is a necessity. The amount of water consumed by animals will depend to some extent on the nature of its food, its siz and functional activity and the seasons. To ensure good health cattle shoul be regularly groomed. They should be washed and bathed once or twice week.

Table 32.3 indicates the average daily requirement of water for different animals.

TABLE 32.3

Cows	27—36 *l*
Pigs	5—23 *l*
Poultry	240 *ml*
Elephant	90—113 *l*
Camel	68—90 *l*

HOUSING

To get the maximum production from animals, it is necessary to provide them protection from excessive rain, heat and cold. The cattle should be housed in comfort in houses with proper sanitation and ventilation. Drinking water should also be made available to them. There should be a proper drainage system and arrangements for the waste removal.

Sheep and goats do not require any special housing arrangements. They can be kept in an open yard, fenced with dried thorny hedges and partially covered with thatched roof Pigs should not be kept in overcrowded and damp houses. Poultry is housed in wire cages or in the poultry houses.

SOME COMMON DISEASES OF ANIMALS

The diseases of animals can be grouped under several categories.

VIRAL DISEASES

1. Pox found in cows, buffaloes, sheep, goats and fowls.
2. Dermatitis found in goats and sheep.

DISEASES CAUSED BY BACTERIA AND FUNGI

1. Tuberculosis in cattle and birds
2. Fowl cholera
3 Contagious bovine abortion
4. Calf diphtheria
5. Necrosis of feet and tail
6. Diarrhoea of chick
7. Foot-rot of sheep.

In addition to these there are several other diseases found in animals. Many of the diseases can be controlled by adopting proper sanitary measures, controlling diets and housing the animals in comfort. Animals should be given vaccination at younger ages.

Everyone benefits from animal husbandry. The farmer benefits from an additional source of income The consuming public benefits from an increased supply of meat, milk and eggs. The nation benefits because of the permanent improvement made in its agriculture and soil conservation made possible by livestock farming. Successful animal husbandry is the basis for sound and continuous soil conservation.

EXERCISES

1. What is a diode ? Explain its action in a rectifier circuit.
2. What do you understand by amplification ?
3. Give a block diagram of a radio broadcast transmitter.
4. Give a block diagram of a radio receiver.
5. Explain the terms modulation and de-modulation.
6. What is ionosphere ? Discuss its role in radio reception and communication.
7. How does the height of a transmitter antenna affects the range covered by a television transmitter ? Give reasons for your answer.
8. Explain the underlying principle of Radar and Sonar.
9. Which of the following materials is used in a transistor (electron device).

   A. Aluminium
   B. Silicon
   C. Arsenic
   D. Tungsten
10. The radio frequency waves travel with a speed of
   A. 300 m/s
   B. 300×10^3 m/s

C. 300×10^6 m/s
D. 300×10^9 m/s

11. Name the raw materials required for manufacture of Portland cement. Draw a labelled line diagram of the kiln used for this purpose Why is gypsum added to Portland cement ?
12. Write the average composition of Portland cement in terms of CaO, SiO_2 and Al_2O_3. What is reinforced concrete ?
13. Name the substances which on mixing together form mortar.
14. Name the raw materials required for manufacturing glass Describe briefly the importance of glass in our daily life.
15. Describe briefly various types of glass known to you. Name the main chemical constituents present in them. Write one important use of each type of glass.
16. Write the approximate chemical composition of glass. How is colour imparted to it ?
17. Write few sentences about the following
    (i) A supercooled liquid
    (ii) Annealing of glass
    (iii) Soda-lime glass
    (iv) Fibre glass
    (v) Pyrex glass
18. What is soap ? Describe a simple method for preparing soap in laboratory or home Why is soap not suitable for washing clothes when the water is hard ?
19. Why are synthetic detergents preferable to soaps for cleaning the clothes when the water is hard ?
20. Complete the following equations/statements :
    (i) $Na_2CO_3 + SiO_2 \longrightarrow \qquad + CO_2$
    (ii) $CaCO_3 + \qquad \longrightarrow CaSiO_3 + CO_2$
    (iii) Oil (fat)+alkalies$\longrightarrow$
21. Write the names of some synthetic fibres which are used in daily life.
22. What is agriculture ?
23. What is horticulture ?
24. What is the position of agriculture in our country ?

25. What are the four important factors which influence crop production?
26. What are the main constituents of soil ?
28. What are the inputs necessary for increasing agricultural production ?
29. Name some agricultural and horticultural crops of your locality.
30. Name the various agricultural practices.
31. Why is it advisable to grow a pulse crop between two cereal crops ?
32. Name the different varieties of rice and wheat commonly cultivated in your locality.
33. Why do the seeds need chemical treatment before sowing ? How can a seed bed be properly prepared ?
34. Why is transplantation required in certain plants ? What are the steps to be taken for proper irrigation ?
35. What are the common weeds found in an agricultural field ? How can they be controlled ?
36. Name a few chemicals which act as plant growth regulators.
37 What do you understand by multiple cropping ?
38. What are the different measures for improving the crops ?
39. What conditions are necessary for proper plant breeding ?
40. Describe artificial pollination.
41. How are the mutations caused ? Is it possible to produce artificial mutation ?
42. Name a few plants which were introduced into our country from outside.
43. Explain why some animals have been domesticated by man.
44. Describe the uses of the following animals : (i) Cow, (ii) Dog, (iii) Camel, (iv) Duck, (v) Pig, (vi) Buffalo, and (vii) Horse.
45. Inspite of the large population of cattle in our country, milk production is meagre— Why ? How do you improve the milk production ?
46. What steps are to be taken for proper management of livestock ?

ANSWERS

Chapter 19

5 (a) 10 per second (b) 20 cm (c) 200 cm/s or 2 m/s 6. 20 c/s

7. 990 m (Hint Assume the velocity of sound as 330 m/s) 8. 447.76 m.

Chapter 20

1. (a)—(v); (b)—(iv); (c)—(vi); (d)—(ii); (e)—(i); (f)—(iii)

2 (a) Real image: 20 cm from the mirror on the same side as the object.
  (b) Real image: 30 cm from the mirror on the same side as the object.
  (c) Virtual image: 40 cm from the mirror on the side opposite to the object.
  (d) Virtual image. 11.1 cm from the mirror on the side opposite to the object.
  (e) Real image: 33.3 cm from the mirror on the same side of the object.

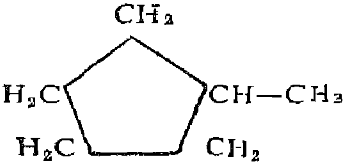
11. (C)

15. (a)—(iii)
  (b)—(iv)
  (c)—(ii)
  (d)—(i)
  (e)—(v)

16. (a) f=30 cm
  (b) 35 cm from the object lens

Chapter 21

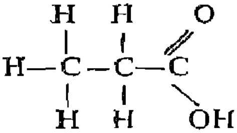
4. (4)



Chapter 22

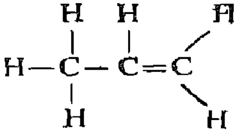
13.

(13) (i)



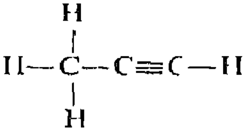
$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$

(ii)



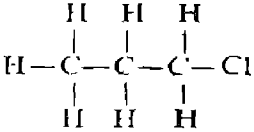
$H-\underset{H}{\overset{H}{C}}-\overset{H}{C}=C(H)H$

(iii)



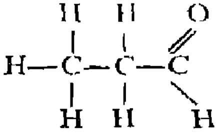
$H-\underset{H}{\overset{H}{C}}-C\equiv C-H$

(iv)



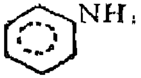
$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-Cl$

(v)



$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-H$

(vi)



Chapter 25

1. (C)

2. (B)

7. (b) All in parallel

8. $\frac{1}{9}$ A; 1 A

9. $8\frac{3}{11}$ A ; 806.67 Ohm

Chapter 26

2. (A)
3. (A)

Chapter 27

4. 0.1 M,

Appendix

The Atomic Masses of the Elements

Element	*Symbol*	*Atomic number*	*Atomic mass*	*Element*	*Symbol*	*Atomic number*	*Atomic mass*
Actinium	Ac	89	(227)	Fermium	Fm	100	(253)
Aluminium	Al	13	26 982	Fluorine	F	9	18,998
Americium	Am	95	(243)	Francium	Fr	87	(223)
Antimony	Sb	51	121,75	Gadolinium	Gd	64	157,25
Argon	Ar	18	39,948	Gallium	Ga	31	69.72
Arsenic	As	33	74,922	Germanium	Ge	32	72.59
Astatine	At	85	(210)	Gold	Au	79	196,97
Barium	Ba	56	137,34	Hafnium	Hf	72	178 49
Berkelium	Bk	97	(249)	Helium	He	2	4 0026
Beryllium	Be	4	9,0122	Holmium	Ho	67	164.93
Bismuth	Bi	83	208,98	Hydrogen	H	1	1,0080
Boron	B	5	10,811	Indium	In	49	114.82
Bromine	Br	35	79.909	Iodine	I	53	126,90
Cadmium	Cd	48	112 40	Iridium	Ir	77	192,2
Caesium	Cs	55	132,91	Iron	Fe	26	55 847
Calcium	Ca	20	40,08	Krypton	Kr	36	83,80
Californium	Cf	98	(251)	Lanthanum	La	57	138.91
Carbon	C	6	12,011	Lawrencium	Lr	103	(257)
Cerium	Ce	58	140.12	Lead	Pb	82	107.19
Chlorine	Cl	17	35.453	Lithium	Li	3	6.939
Chromium	Cr	24	51.996	Lutetium	Lu	71	174 97
Cobalt	Co	27	58.933	Magnesium	Mg	12	24 312
Copper	Cu	29	63.54	Manganese	Mn	25	54 938
Curium	Cm	96	(247)	Mendelevium	Md	101	(256)
Dysprosium	Dy	66	162 50	Mercury	Hg	80	200.59
Einsteinium	Es	99	(254)	Molybdenum	Mo	42	95.94
Erbium	Er	68	167,26	Neodymium	Nd	60	144.24
Europium	Eu	63	151,96	Neon	Ne	10	20,183

Element	*Symbol*	*Atomic number*	*Atomic mass*	*Element*	*Symbol*	*Atomic number*	*Atomic mass*
Neptunium	Np	93	(237)	Selenium	Se	34	78 96
Nickel	Ni	28	58 71	Silicon	Si	14	28,086
Niobium	Nb	41	92,906	Silver	Ag	47	107 87
Nitrogen	N	7	14 007	Sodium	Na	11	22,990
Nobelium	No	102	(253)	Strontium	Sr	38	87 62
Osmium	Os	76	190 2	Sulphur	S	16	32,064
Oxygen	O	8	15.999	Tantalum	Ta	73	180.95
Palladium	Pd	46	106 4	Technetium	Tc	43	(99)
Phosphorus	P	15	30.974	Tellurium	Tc	52	127 60
Platinum	Pt	78	195 09	Terbium	Tb	65	158.92
Plutonium	Pu	94	(242)	Thallium	Tl	81	204.37
Polonium	Po	84	(210)	Thorium	Th	90	232 04
Potassium	K	19	39 102	Thulium	Tm	69	168.93
Praseodymium	Pr	59	140,91	Tin	Sn	50	118 69
Promethium	Pm	61	(145)	Titanium	Ti	22	47.90
Protoactinium	Pa	91	(231)	Tungsten	W	74	183 85
Radium	Ra	88	(226)	Uranium	U	92	238 03
Radon	Rn	86	(222)	Vanadium	V	23	50 942
Rhenium	Re	75	186 2	Xenon	Xc	54	131 30
Rhodium	Rh	45	102,91	Ytterbium	Yb	70	173.04
Rubidium	Rb	37	85.47	Yttrium	Y	39	88,905
Ruthenium	Ru	44	101.07	Zinc	Zn	30	65.37
Samarium	Sm	62	150.35	Zirconium	Zr	40	91.22
Scandium	Sc	21	44.956				